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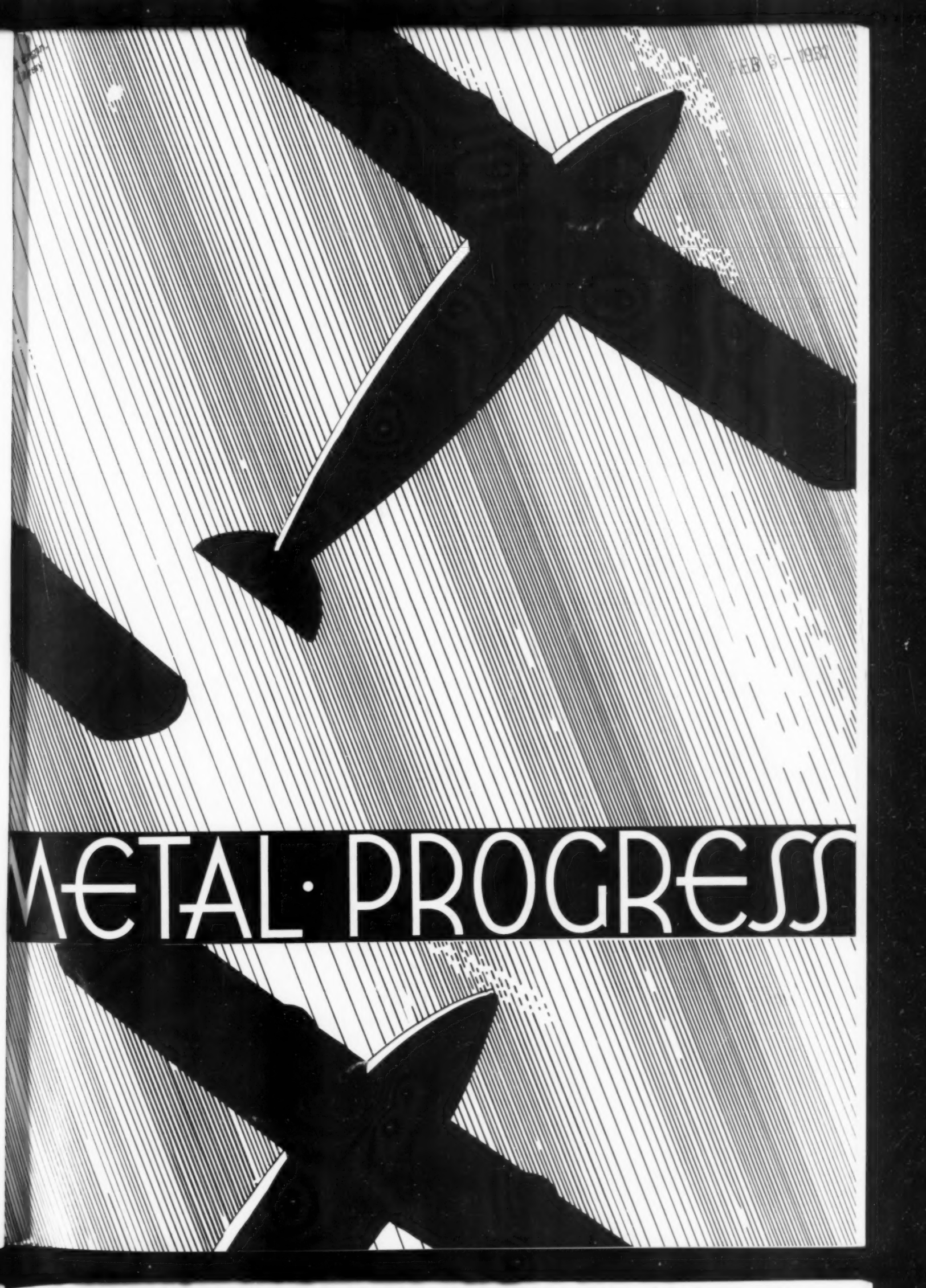

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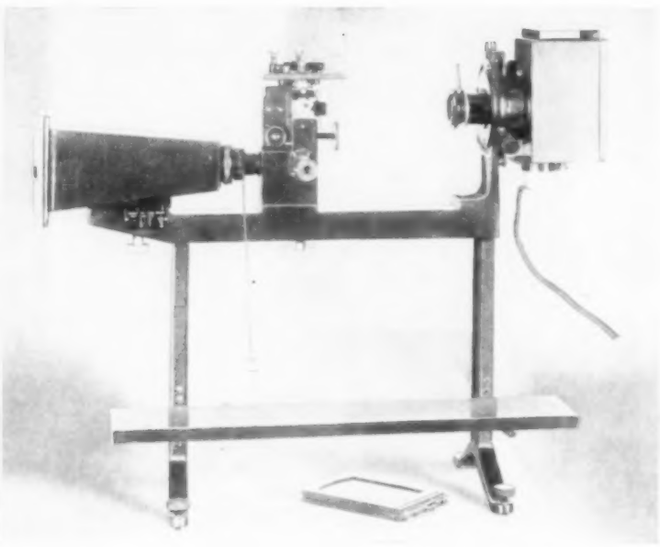

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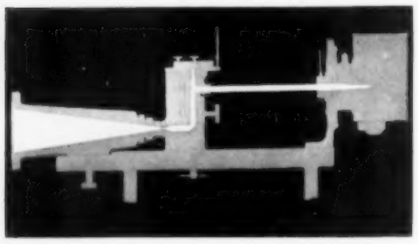

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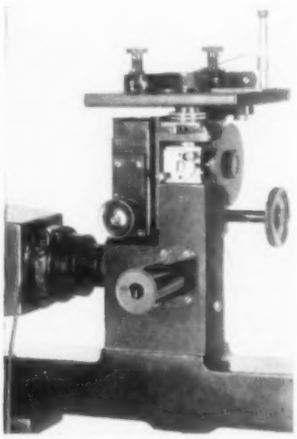

The fine adjustment carries only the weight of the objective, and is so constructed that it is not affected by the heat from the illuminant.

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METAL PROGRESS

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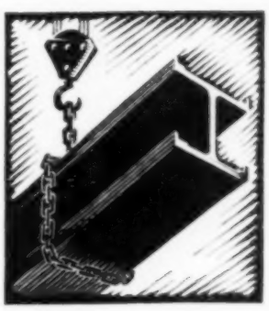

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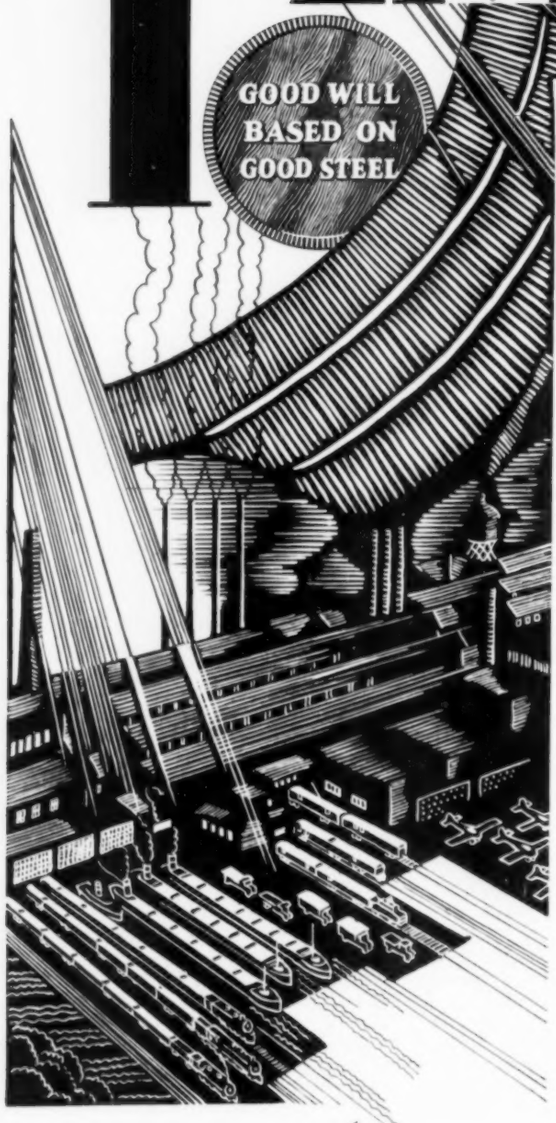

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IN THIS ISSUE

D. A. Nemser

H. S. Rawdon

G. E. Shubrooks

R. J. Cowan

DAVID A. NEMSER, author of the description on page 23 of the equipment and technique used in the heat treatment of small tools at Pratt & Whitney Co., is chief metallurgist of that organization. After graduating from Carnegie Institute of Technology, Mr. Nemser was successively associated with Souther Engineering Co., Hartford, MacBeth-Evans Glass Co., Charleroi, Pa., and Ludlum Steel Co., Dunkirk, N. Y., before joining Pratt & Whitney.

The chief of the metallurgical division of the United States Bureau of Standards, HENRY S. RAWDON, prepared the article on the effect of cold upon metals which begins on page 29. Mr. Rawdon was born in England but was educated in this country, graduating from Michigan State Normal College and the University of Michigan. At the university he was private assistant to the late Prof. E. D. Campbell. Since 1912 he has been associated with the Bureau of Standards. Publication of this paper was approved by the Director of the Bureau of Standards of the U.S. Department of Commerce.

High carbon, high chromium stainless is discussed on page 49 by H. T. MORTON and I. A. RUMMLER, respectively metallurgist and assistant metallurgist of Hoover Steel Ball Co. This is the sequel to the paper they wrote for the last issue of METAL PROGRESS.

An unusual application of metal is described on page 58 by G. E. SHUBROOKS, chief chemist of Hamilton Watch Co. He joined this company in 1926 after having been connected with one of the General Motors divisions as assistant in the physical testing division and later in the chemical laboratories.

The metallurgical experience of R. J. COWAN, whose discussion on continuous gas carburizing begins on page 44, is wide, including as it does eight years in the laboratory of a steel works, ten years in charge of the laboratory of a malleable iron plant, and eight years in general metallurgical and foundry research. He is now research metallurgist for Surface Combustion Co. at Toledo.

On page 39 Dr. G. E. DOAN, associate professor of physical metallurgy at Lehigh University, concludes his all too brief series of articles on welding.

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ON

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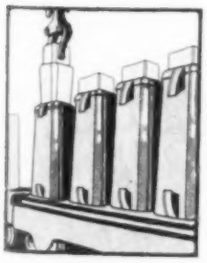
Speed-inviting concrete roads—seamy, bumpy, unpaved detours, the motor coach travels them all . . . . . New York to San Francisco, or Jonesport to Wilkins Corners—the safety and dependability of motor coach service depends on parts made of sound steel . . . . . The first step in making sound steel is to produce a sound ingot . . . . . Gathmann Molds produce sound ingots.



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SOUND STEEL DEPENDS ON THE INGOT

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The Hardener

HEAT TREATMENT OF SMALL TOOLS

with modern equipment and technique

By David A. Nemser
Chief Metallurgist
Pratt & Whitney Co.
Hartford, Conn.

HEAT treating of steel, especially small steel tools, is far from being an exact science, but within the past few years it has become a much more controlled art. While perfection has not been attained, the past few years have witnessed a long advance in the quality of furnace room equipment. Some of these advances include automatic control on all types of furnaces, controlled atmosphere in electric box-type furnaces, electric resistors for high heats, and automatic timing for all operations. There is still much work to be done by the furnace builder and the metallurgist to perfect the equipment now available, for without question it still is possible to improve the metallurgical qualities of heat treated tool steels. Laboratory studies have proven this statement.

In general terms, the hardening problem involves other things than merely heating and cooling. First the desired physical requisites for each tool must be ascertained, the commercial steels selected, and the best heat treating specifications determined by laboratory research. The second consideration, which is of equal importance, is the ability to turn out a duplicate product in mass production. These primary considerations determine the hardening equipment to be used. The initial cost of installation and the cost of operation are important, but are necessarily secondary.

A brief explanation of the last statement is in order. The user of a small tool will primarily demand accuracy, granting that the metallurgical qualities of hardness and toughness are present. Therefore, it is important that distortion and scaling in the heat treatment should be minimized. For example, the pitch diameter, the outside diameter, and the angle of a threaded tool made of high speed steel (such as a cut thread tap or a cut thread hob) must be maintained within close tolerances. It is apparent that excessive or irregular scaling will scrap the tool, since there is no way of salvaging it.

Furthermore, since scaling is most intense

at the crest of the thread, excessive corrosion tends to blunt the angle, thus destroying its accuracy. This fault appeared frequently when using the older types of high speed furnaces, but has been greatly minimized by the new developments.

It also is true that some portion of the surface of nearly all hardened small tools is either unground or unpolished. Such surfaces must be smooth and free from pits. Decarburization or excessive carburization of the surface must also be avoided in order to present a representative surface to the temper tester.

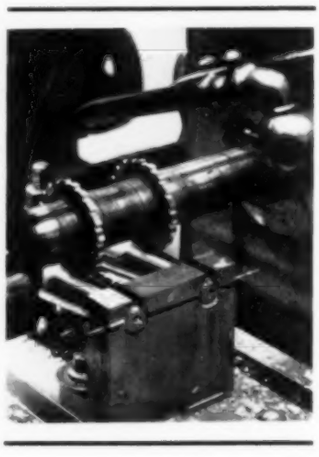
Three Classes of Steel Used

It is my purpose in this article to describe briefly the practice of small tool hardening at the Pratt & Whitney Co. Products include taps, dies, milling cutters, reamers, chasers, end mills, counterbores, punches, and a line of miscellaneous small tools which are manufactured in large quantities. There are three classes of steels now employed for most of our small tools:

1. Water hardening tool steel (either plain carbon steel or with small percentages of chromium or vanadium),
2. Oil hardening tool steel, and
3. High speed steel.

Hardening equipment has been selected to accommodate these three classes, subject to the other considerations mentioned above. The principal factors involved in this selection were uniformity of heating, a minimum and uniform scale (particularly on high speed steel), uniformity of quenching and of tempering.

Our hardening department for small tools consists of two rooms, a large one 150 ft. long and 50 ft. wide, principally for hardening, and an adjoining smaller room 60 ft. long and 25 ft. wide for tempering operations. In the larger room, equipment for hardening carbon steel is arranged along one wall, and high speed steel and oil hardening tool steel on the opposite. Location of furnaces and quenching tanks, as well as benches for holding the pans of work in process, the tongs, racks, and other fixtures, has been worked out with great care so that everything is in proper and efficient relation. Equipment is not crowded, which makes it easy to keep the department clean and orderly.



High ceilings and well-insulated furnaces keep down the room temperature even in the hot summer, and adequate ventilation sweeps the air clear of unavoidable odors from quenching tanks. All windows have green glass panes; artificial light is provided by a carefully placed battery of mercury vapor lamps. In this way the intensity of illumination is constant despite the outside weather, a most desirable feature even when there is no lack of pyrometric control instruments.

At one end of the hardening room various straightening presses are located, and opposite these are the welding machines for joining medium carbon shank steel to high speed steel or carbon tool steel bodies.

Every detail of the hardening operations for each tool or group of tools put through is carefully watched, recorded, and checked. Each order coming into the department has its own hardening record card. As its name implies, this card indicates the exact thermal treatment to be carried out, and the reverse side contains a description of the tool. These instructions are made out in the metallurgical office, where a complete record is kept of the thermal treatment for every tool manufactured by Pratt & Whitney. The type of hardening equipment to be used, the time at heat, the quenching medium, the drawing schedule, and the desired Rockwell and file hardness have all been worked out in detail. These data are grouped for each type of tool and are maintained in an open file for easy reference by the staff.

The function of this card is quite simple but nevertheless it is very complete in its scope. The hardeners, all of whom have had considerable experience, can see at a glance just what time cycle to set on the automatic timer and what temperature to operate the furnace

or furnaces. After the completion of the work or operation called for he must sign the card. Next, the operator in charge of tempering must likewise observe the instructions, perform the work, and sign the card to certify that his work has been carried out as directed. The temper tester completes the record by affixing his signature after a thorough inspection of the lot.

with a rating of 20 kw. up to 14 in. diameter and 22 in. deep (rated at 30 kw.) They are equipped with automatic indicating controllers which maintain the temperature very accurately.

An automatic timing device, previously set for the desired time cycle noted on the job card, is actuated by the rack from which the work-holding tongs are suspended. When the time

Globar High Speed Furnaces With Preheaters, Both Having Gas Curtains

These hardening record cards are filed for a period of three years for reference purposes, and are of great value.

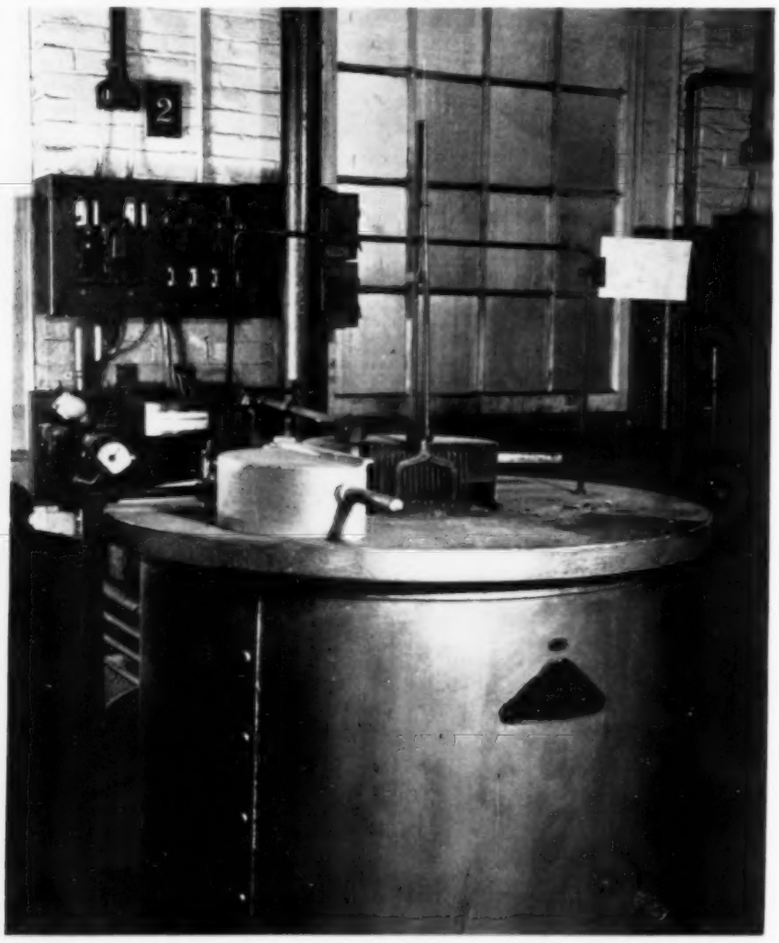
Shank tools, such as taps and reamers, made of water hardening tool steel, are heated in lead baths. Tools are held in multiple or "machine" tongs. Small tools, such as dies, are wired together in groups and are heated in the same baths.

These electrically heated lead baths range in pot size from 10 in. diameter by 18 in. deep

cycle for heating has been completed, a light flashes and the operator removes the work from the bath and quenches it in brine (or gives it an interrupted brine and oil quench if the piece is large or intricate).

Operation of Lead Pots

Care given the lead pots will be labor well spent. We maintain a layer of granular hard wood charcoal on the surface of the molten lead



Lead Pot With "Machine" Tongs Carrying a Batch of 17 Tools. Record card is clipped to standard at right. At rear is electric heat control, indicating pyrometer, and automatic timer. On next page is shown the control equipment for six oil baths, heated by immersed resistors

to minimize oxidation and lessen the formation of dross. Dross will cling to the threads of tools, causing "dirty" work. It also corrodes unduly the pot itself. The surface of the lead is skimmed twice daily, and the sides of the pot carefully scraped down. A fresh layer of charcoal is added after cleaning, and further additions must be made as it is consumed.

Pots of heat-resisting alloy are used throughout the hardening room. Many of these have given 20,000 heat hours without any indication of failure. Clean, pure lead together with moderate temperature (1500 F. seldom is exceeded in operations at Pratt & Whitney) greatly prolongs the life of such pots.

Quenching brine is refrigerated automatically and is maintained at 60 to 70 F. with a salt concentration of 10 to 12%. This control is important; it eliminates the tendency to crack tools or produce soft spots. A recognized brand of quenching oil is used.

Tools made of water hardening tool steel, and of sufficient bulk and of compact design, are hardened in box-type electric furnaces. (These include various milling cutters, large chasers, dies, and punches.) The same furnaces also are used for tools made of oil hardening tool steel, and for flat tools of carbon tool steel such as metal slitting saws and screw slotting cutters. Tools of the latter type require suitable press quenching fixtures to insure proper flatness.

These furnaces are heated by the conventional metallic resistors and are provided with automatic indicating controllers and equipped with gas curtains for maintaining a suitable atmosphere. For ordinary tool sections, furnaces with hearth dimensions of 12x24 in. rated at 15 kw. are used. Larger tools require preheating, and this operation is carried out in similar electric furnaces at 1200 F. A furnace 24x18 in. and 54 in. deep, rated at 30 kw., is employed for the heavier tools.

Experience With Gas Curtains

It has been found by experiment that work quenched in brine does not need to be heated in a furnace with a gas curtain if the door has been kept closed during the heating cycle. The scale "peels" nicely, and uncovers a file-hard surface, free of soft spots.

On the other hand, it is imperative that the gas curtain be employed for work that is to be

oil quenched. If this precaution is not taken, a soft skin and pitted surface will probably result. The lead bath does not lend itself to oil hardening tool steel, as a soft skin ordinarily is produced.

Tools of water hardening steel, heated in box-type electric furnaces, are quenched directly in refrigerated brine — or, if the parts are large or of intricate design, they are given an interrupted brine and oil quench. Obviously, tools of oil hardening steel are quenched directly in oil. Straightening is done before tempering.

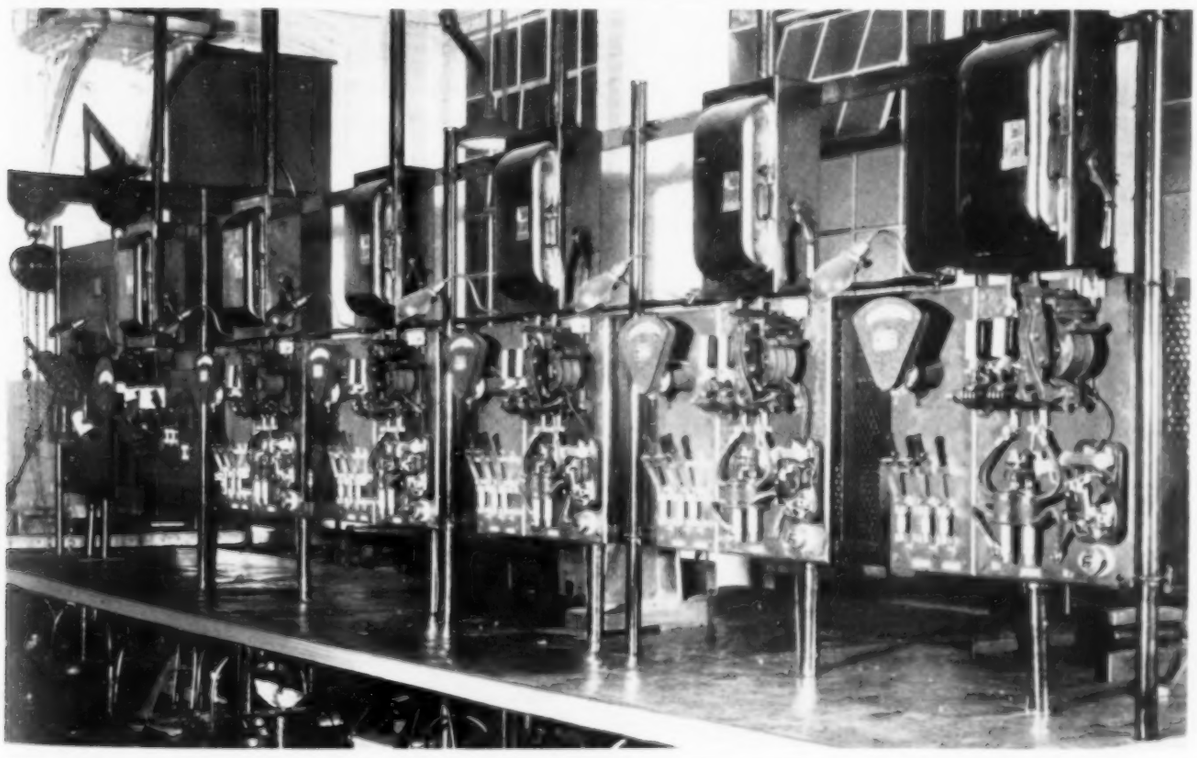
High speed steel hardening is carried out in electric furnaces equipped with Globar heating elements, provided with recording pyrometric control, and ordinarily operated at 2310 to 2350° F. Each furnace also has a gas curtain for controlling the furnace atmosphere; it minimizes scaling and eliminates "alligator skin," characteristic of a highly oxidized surface. This type of furnace provides a system in which the atmospheric control is independent of the thermal input.

Due to the nature of the parts being hardened, the high speed furnaces are operated with the doors open. However, in order to make the gas curtain most effective, the door openings have been bricked down to 6x6 in. An asbestos shield, clearly shown in the view on page 25, is suspended in front of the door. This precaution makes working conditions far more comfortable. Tools can be watched with minimum eye strain and fatigue through a pane of green glass inserted in the shield at the working level. These seemingly minor details contribute to the maintenance of a high standard of quality.

High Speed Preheat

For preheating high speed steel, electric box-type furnaces of the metallic resistor type are used. These also are provided with gas curtains and are automatically controlled. They are operated at 1550° F. and their dimensions coincide with those mentioned above in connection with carbon steel.

Comparatively small furnaces take care of the smaller tools; hearth dimensions are 30x12 in., and rating is 50 kw. For large work, a



Globar-heated furnace with a hearth 34x16 in., rated at 60 kw., is used. The door is bricked down to 8x8 in. to make the most effective use of the gas curtain. Two box-type electric furnaces with hearths 30x16 in. (20 kw. rating) serve as preheating units. Both of these are provided with gas curtains. The first is operated at 1200 F. and the second at 1650 F.

Standard File in Skilled Hands Best Test for Cutting Edges

Tongs and Fixtures

Considerable study has been given to the development of suitable handling facilities for small tools during hardening operations. The very small tools are placed on nickel trays. Taps are inverted in nickel blocks, each holding six to twelve, depending on diameter or size. Large tools are handled individually with tongs resting on a thin firebrick ("split") placed on the furnace floor. These bricks are inexpensive and may be replaced frequently, a practice which avoids the fluxing action when tools encounter a dirty hearth.

High speed steel tools are quenched either in oil or molten lead baths, and are also straightened before tempering.

Nearly all tools of carbon steel or oil hardening tool steels are drawn in a battery of six electrically heated and automatically controlled oil baths. These are tanks 30x20x24 in. deep, equipped with immersion heating units. Such baths are used for temperatures up to 500 F. During this process flat tools are placed on arbors between heavy plates. If higher temperatures are desired, special air drawing furnaces, electrically heated and automatically controlled, are employed.

All high speed steel tools except thin, flat cutters are drawn in a large rectangular lead bath wherein a tempering treatment, designed to develop secondary hardness, is given them. The bath is electrically heated and controlled by a two-point controller. A temperature range of 1050 to 1200 F. covers high speed steel tool requirements. The pot is 40 in. long by 20 in. wide by 18 in. deep and contains 4500 lb. of lead. Large tools are introduced into the pot individually, while small parts are packed into perforated baskets between layers of charcoal. This precaution is necessary to prevent the lead from sticking. Heavy covers operated by compressed air submerge the work. Thin, flat tools are drawn on arbors in the air drawing furnaces mentioned above.

Pickling Hardened Tools

After tempering, high speed steel tools are pickled in acetic acid. This operation, which requires approximately 8 hr., softens the scale but has no measurable action on the steel. Tools are then mud blasted (wet sand blasted) which produces a smooth surface of a pleasing gray color. Large carbon steel tools are also mud blasted, but are not pickled. Small carbon steel tools are brushed up on a wire wheel.

Temper testing is the final operation in the hardening process. Only inspectors of long experience can qualify, for it is their responsibility to see that improperly hardened tools are not shipped. A predetermined percentage of every order is inspected for Rockwell hardness, and in addition tested with the file. All files used for this purpose are purchased on definite specifications, and each one is tested after receipt for its cutting properties on standard test pieces. The temper tester must check the temper of the cutting edges of the tools, the toughness of the shanks, the selective hardening (on certain tools) and any other item that might be indicated on the hardening record card.

In conclusion, it should again be emphasized that the furnaces and other equipment described above have been selected and organized into a complete unit for one object only — to maintain high quality in the product. The workmen are given every device which we are convinced will help them to put out, day by day, small tools of uniform and high cutting ability and fine appearance.

COLD TREATING METALLIC ALLOYS

effect of cooling in liquid air or dry ice

By H. S. Rawdon
Bureau of Standards
Washington

IMPROVEMENT in the properties of metals has been accomplished from time immemorial by means involving heat and the two ideas have come to be almost complementary concepts. The fact that the *rate* at which the heat is abstracted from a metal (that is, the rate of cooling from a high temperature) is a factor of preponderating importance is not always fully recognized. Still less so is the fact that the properties of some metals may be very materially changed by cooling them below the temperature at which they are ordinarily used, that is, below "room temperature." It is with this aspect of the subject that this note deals.

Changing Dimensions

The first practical application of the effect of cold on metals which naturally occurs to one is dependent on the well-known property of contraction and expansion. The conventional ball-and-ring experiment in physics for demonstrating this fundamental property has been used for years in explaining the method of producing "shrink" fits, that is, by warming the ring and allowing it to contract around the ball and form a "shrink fit" as it cools to room temperature.

The converse method of fitting the ball and ring together, which depends on cooling the ball and allowing it to expand within the ring, has usually received only brief mention, probably on account of the supposed commercial impracticability of the operation. This situation has changed, however. It was shown by H. L. Whittemore 10 years ago, in tests carried out at the Bureau of Standards with liquid air and explosives for tightening body-bound bolts (*American Machinist*, 1922, page 524), that the use of liquid air for producing such tight fits was entirely feasible. The method has not been very widely used, however, largely because of the inconveniences encountered in transporting and storing liquid air.

It should be mentioned in passing that one of the leading producers of compressed oxygen for cutting and welding purposes is prepared to make shipments of liquid air in long-necked "vacuum bottles" containing 25 liters of liquid. Evaporation is from 4 to 8% per day, so shipments should be made just prior to use. It has a boiling point of approximately —310° F., and

Cooling a 5-In. Piston Rod End With Liquid Air Before Making Expansion Fit Into Tapered Socket in Piston. Courtesy Air Reduction Sales Co.

the evaporation of one liter will extract about 200 B.t.u. of heat from the part being cooled and the insulated container.

Advent of solid carbon dioxide as a common refrigerant has put this method on a more practicable basis. By the use of "dry ice" in a bath of acetone, a temperature of —110 F. can be easily attained. The decrease in dimensions produced by cooling a metal in this manner from room temperature, a difference of approximately 200° F., is frequently sufficient to produce the necessary difference in dimensions for assembling two parts which are to be fitted together. This is illustrated in the figure which shows an assembled ring and pin. The 1-in. brass pin was cooled with a mixture of dry ice and acetone, the brass ring (at room temperature) was then slipped on and the bolt allowed to expand.

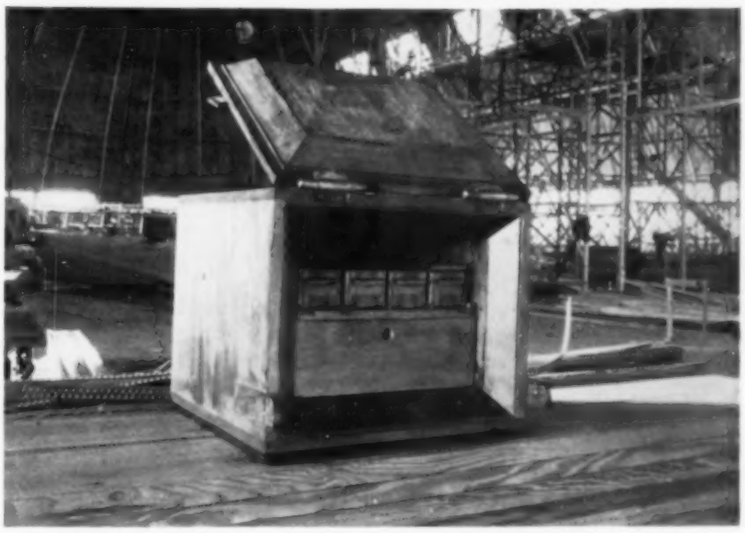
Data relating to this expansion fit are as follows: Material was a yellow brass, free-cutting stock, with coefficient of expansion of 0.000010 in. per in. for 1° F. (This is an average value at room temperature; the slight decrease for lower temperatures has not been taken into account.) Dimensions of the parts at room temperature were: Width of ring, 0.97 in.; inner diameter of ring, 0.9992 in.; diameter of pin, 1.0004 in.; "over size" of pin, 0.0012 in. Change of temperature on cooling was about 180° F., which decreased the diameter of the pin 0.0018 in., making its diameter, cold, 0.9986 in., and giving a diametral clearance between ring and cold pin of 0.0006 in. No difficulty whatsoever was met in slipping the ring on the pin after cooling the pin. No driving was necessary. In fact, the film of acetone covering the pin appeared to act as a lubricant and to aid quick assembling.

Maximum frictional resistance developed in pulling the ring from the pin after the unit had been allowed to come to room temperature was 1430 lb. per sq.in.

A material having a much smaller coefficient of linear expansion than brass may not shrink enough in dimensions when cooled in a bath of dry ice to make a tight fit in the manner illustrated above. This is true of steel, the coefficient of linear expansion of which — considerably less than the figure for brass — is about 0.000006 in. per in. for 1° F. The difficulty is easily avoided, however, by warming the ring in hot water before attempting to fit it on the cooled pin.

Information on a fit made of cold rolled low carbon steel in this manner is summarized as follows: Width of ring is 1.00 in., and its inside diameter at room temperature is 1.0008 in. Diameter of pin at room temperature is 1.00225 in., making the "over size" of pin 0.0014 in. Diameter of pin, cooled with dry ice to —110 F., was reduced to 1.00115 in., and the inside diameter of ring, warmed in boiling water (212° F.), became 1.00168 in., making the diametral clearance between cold pin and warm ring 0.00053 in.

On attempting to pull the ring from the pin after the assembled unit had been allowed to come to room temperature, evidence of slip occurred at a frictional resistance of 1820 lb. per sq.in., after which "seizing" occurred and a



One of the Refrigerators at Goodyear Zeppelin Corp. (Builders of Dirigibles for U. S. Navy) for Holding Duralumin Rivets. Design was from suggestions received from Boeing Airplane Co., Seattle

maximum holding resistance of 6050 lb. per sq.in. was developed.

Producing tight fits by refrigeration has several distinct advantages over the conventional method which depends upon heating the outer metal part and "shrinking" it on the inner one. It is, of course, now limited in applicability to small sized parts but has the marked advantages of speed, cleanliness and freedom from surface scaling or discoloration as well as other annoying features associated with the strong heating of metals.

Retarding Phase Changes

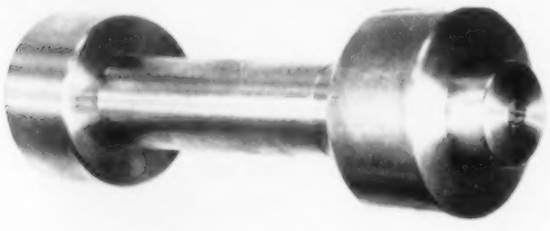
The effect of cooling on structural changes in metals is two-fold. Phase changes which, if given sufficient time, would complete themselves at ordinary room temperature can be retarded indefinitely by maintaining the material at a sufficiently low temperature. On the other hand, there are a few changes which can be accelerated by cold.

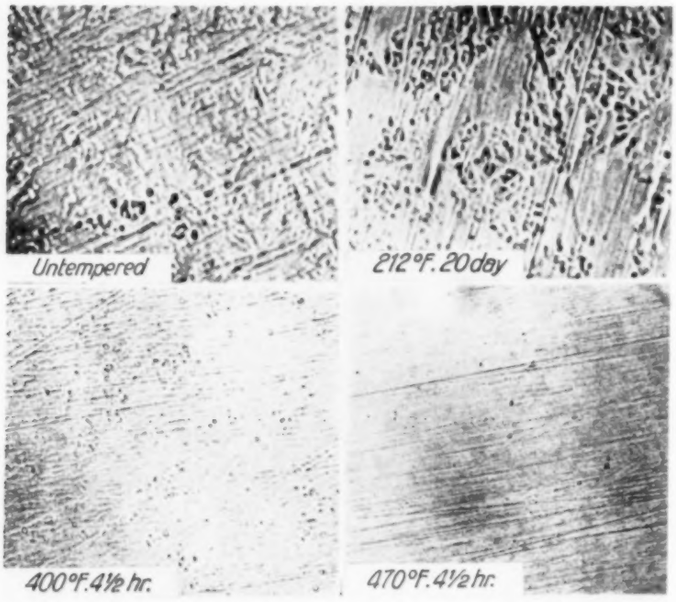
A striking example of the use of a refrigerant for controlling at will the consummation of a phase change after heat treatment is encountered in the use of duralumin. The method by which the mechanical properties of this alloy can be improved is so well known that only brief mention is necessary here; this general method of "precipitation hardening" is frequently referrd to as the "duralumin type of heat treatment."

In the annealed or structurally stable condition, duralumin has a duplex structure, of which by far the greater part consists of a relatively soft matrix in which are embedded the hardening constituents, the particle size and distribution of which depend upon the previous metallurgical history of the alloy. When heated to a temperature somewhat above 950° F. most of these embedded constituents are absorbed in solid solution in the matrix. This structural condition can be maintained by quenching, but if allowed to stand at room temperature the dissolved constituents precipitate progressively with time in an extremely fine condition throughout the matrix, the change being accompanied by a marked increase in hardness and strength.

In some alloys of aluminum, as well as other metals, slight heating (tempering or drawing) is necessary to bring this structural change about. In duralumin, however, it occurs readily at room temperature, although slowly, and time is required for its consummation. Evidence of the change is often apparent after one hour's

One-Inch Brass Pin and Ring Assembled by Expansion Fit. Pin was cooled by dry ice, shrunk 0.0018 in., and slipped into ring remaining at normal temperature





Pieces of 1.12% Carbon Tool Steel Were Quenched From 1925 F., and Surfaces Carefully Polished. One was then immersed in liquid air, the others were tempered as shown and then immersed in liquid air. "Rufflings" on surface are ascribed to changes in unstable martensite

aging and after two hours the change is well under way. After four days no further marked change in the properties occurs.

Any necessary severe deformation, such as cold working, must be done, therefore, before the hardening process has progressed to any appreciable extent. For years the regulations for the use of heat treated duralumin rivets were that they be used within 30 min. after being quenched, although an extension of this period to 60 min. was allowed by some.

Dix and Keller, following a clue based on some observations made during severe winter weather by workers in an airplane factory, have shown in a paper before the Institute of Metals Division, A.I.M.E., in 1931 how the hardening process in metals of the duralumin type can be retarded by keeping the quenched alloy very cold. The practice of keeping freshly quenched duralumin rivets cold until ready for use by means of dry ice is now quite generally followed by users of these materials. In this way, the precipitation of the dissolved constituents in solid solution in the duralumin matrix is prevented and the alloy can be maintained in the relatively soft condition as long as may be desired. In the case of rivets, this is until the rivets have been driven. After the driven rivets warm up to room temperature, the structural or precipitation change occurs naturally and the rivets take on the hardness and strength which are necessary for their use in a high strength duralumin assemblage.

Of course, this treatment is exactly analogous to that necessary in other precipitation hardening alloys which harden only when tempered after quenching. Normal room temperature is low enough to retard the precipitation process in such alloys, just as the temperature of the dry ice retards changes in duralumin. Heating subsequent to cooling occurs "naturally," however, in those cases in which the cooling below atmospheric temperatures is produced artificially. In one class of operations, energy is expended in cooling below room temperature to the desired low temperature; in the second and more usual class, energy is expended in heating above the low temperature in use, which is room temperature.

Accelerating Phase Changes

A classic example of the accelerative effect of cold upon a structural change in a metal is the transformation of tin from the familiar malleable form into a gray powder. A recent application of the method to certain austenitic steels is of more immediate practical interest, however.

The effect of severe cooling on steels, particularly those in the heat treated condition, with martensitic or austenitic microstructure, has been a favorite problem for metallurgists ever since suitable refrigerants, especially liquid air, became available. The assumption in such experiments has been that the normal transformation of iron from the austenitic or gamma condition to the familiar alpha state has been suppressed by the alloying elements present in

the steel and the change cannot complete itself on account of the "sluggish" nature or rigidity of the material at the relatively low temperature of the atmosphere.

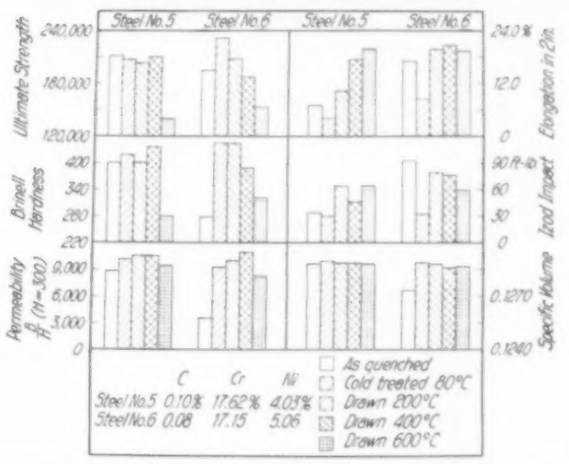
Only in a very few special cases has it been possible to show that a transformation in the austenite has been brought about by severe cooling. Such negative results should not cause surprise for the following reasons:

According to the generalization of physical chemistry usually called Le Chatelier's principle, the change favored or induced by any constraint on a system in equilibrium is of such a nature that its occurrence will tend to lessen the constraint. If the constraint is an increase in pressure, as is actually the result of thermal contraction of a steel during severe cooling, the change which tends to occur is one which entails a decrease in specific volume so that its consummation will result in relieving the pressure on the steel. On the other hand, the change from gamma iron to alpha iron (the decomposition of austenite) is accompanied by a pronounced dilation or increase in specific volume. Therefore, attempts to harden stable austenitic steels by "cold treatment" are generally not expected to be very successful.

A series of micros, taken from Bureau of Standards Scientific Paper No. 452, by S. Epstein and the writer, will serve to illustrate structural changes produced in a hardened high carbon steel by immersion in liquid air. Cooling the martensitic matrix of such a steel resulted in volume changes within this unstable phase which manifested themselves as a "ruffling" of the polished surface.

Whatever the nature of this change may be, it is not reversible. On immersing the same specimen a second time after repolishing it at room temperature, only very slight and scarcely perceptible evidence of a change in the martensitic matrix was observed. The austenitic patches, on the other hand, continued to show their presence in the polished-and-cooled specimen even after prolonged heating at slightly elevated temperatures. It was evident that the austenite in quenched 1.12% carbon steel did not respond to the cold treatment.

Luerssen and Greene, and Krivobok and Gensamer last year made outstanding contributions to the subject of the effect of cold on



Effect of Cold Treatment With Dry Ice on the Properties of High Nickel-Chromium Steels. Data from Luerssen and Greene

austenitic steels to the A.S.S.T. and the A.I.M.E. respectively. They have shown that, within a narrow range of composition, that is, the so-called "marginal" or "borderline" steels, marked changes in the properties of the steels can be brought about by severe cooling and that decomposition of the austenite accompanies these changes in properties.

Results shown in the diagram, which has been replotted from data given by Luerssen and Greene, indicate the magnitude of the change in properties which may be produced by cold treatment with dry ice as well as the relatively slight difference in composition between steels which respond and those which do not respond to cold treatment. The work of Krivobok and Gensamer supplements this by showing that differences in carbon content as well as differences in the alloy content, play an important part in determining whether or not an austenitic steel will respond to refrigeration.

There can be no doubt as to the validity of the conclusions of these investigators that decomposition of austenite in certain steels can be produced by cold treatment. A satisfactory explanation of the narrow composition limits within which such steels lie is still forthcoming. Evidently this behavior is associated with a condition of pronounced instability of the austenitic phase in these steels.

Photo by Rittase

Courtesy Henry Disston & Sons, Inc.

The Rolling Mill

LOW ALLOY STEEL FOR STRUCTURES

has good properties without heat treatment

By Richard Tull
Electro Metallurgical Co.
New York

FOR many years various attempts have been made to produce a low-alloy steel that could be used for general engineering purposes. Probably one of the first successful experiments in this field was the use of the so-called silicon structural steel, which increased the carbon approximately 15 points to 0.40%, and instead of a vanishing amount of silicon contained in the ordinary basic structural steel, had from 0.25 to 0.45% of this element. Such steel can be depended upon to carry 40% greater load than carbon structural steel, and has been used in the main members of many important bridges and a few buildings.

The next step introduced the medium manganese alloy steels, the applications of which have increased steadily during the past few years, particularly for rails and structural shapes. In every case the problem was principally one of providing a comparatively low-priced steel that would develop the required physical properties either in the as-rolled condition or as a result of a simple normalizing process. High yield point (or, more strictly speaking, "true elastic limit") is desired by designers of long arch or suspension bridges, and the medium manganese steel containing carbon 0.30 to 0.40% and manganese 1.60 to 1.80% is particularly advantageous in this respect, giving a minimum yield point about 5000 lb. higher than the silicon structural steel.

Silicon-manganese steels (with carbon about 0.40%, silicon 0.30%, and manganese 1.50%) have been used to some extent abroad for strong structural steels in the as-rolled condition, but over here this type of steel has been confined to specialties like compressed gas cylinders, tough steel castings, and high strength welding rod.

Study at Union Carbide & Carbon Research Laboratories, Inc., led to the addition of chromium to these silicon-manganese steels and has resulted in the development of the series of low-alloy steels we have called "cromansil" steels. It was found that low alloys of these low-cost alloying elements gave superior properties — especially a combination of high strength and ductility.

The term "cromansil" is not intended to be the trade name of a special grade of steel, but may logically be used to designate the type of structural steels whose composition lies within the recommended range of alloy content. It is

obviously derived from the three alloying elements involved in their composition — chromium, manganese, and silicon.

The group or type was extensively studied in the form of heats in a small induction furnace, but enough information is now available about their commercial production to warrant the statement that they are easily manufactured by the open-hearth process, and are especially valuable for those applications where a high grade steel is to be used in the as-rolled condition. Heat treating will, of course, further develop the favorable physical properties, but in the as-rolled condition, greater strength and ductility can be attained than is possible with any of the plain carbon steels.

Function of Three Alloys

The alloy limits most widely used are from 0.4 to 0.6% chromium, 1.1 to 1.4% manganese, and 0.7 to 0.8% silicon, with the carbon content ranging from less than 0.10 to 0.65% to meet the requirements for certain specific uses. Staybolts should contain not over 0.10% carbon. Boilers and pressure vessels (welded or riveted) can carry 0.17 to 0.22% carbon, while large tonnages of high strength seamless tubing in the form of oil well casing have been made with 0.30 to 0.35% carbon.

Heat treated parts would contain from 0.35 to 0.65% carbon depending upon the physical properties desired. For special applications the variations in composition can be extended to 0.2 to 0.7% chromium, 1.0 to 1.8% manganese, and 0.3 to 1.0% silicon, depending upon the purpose.

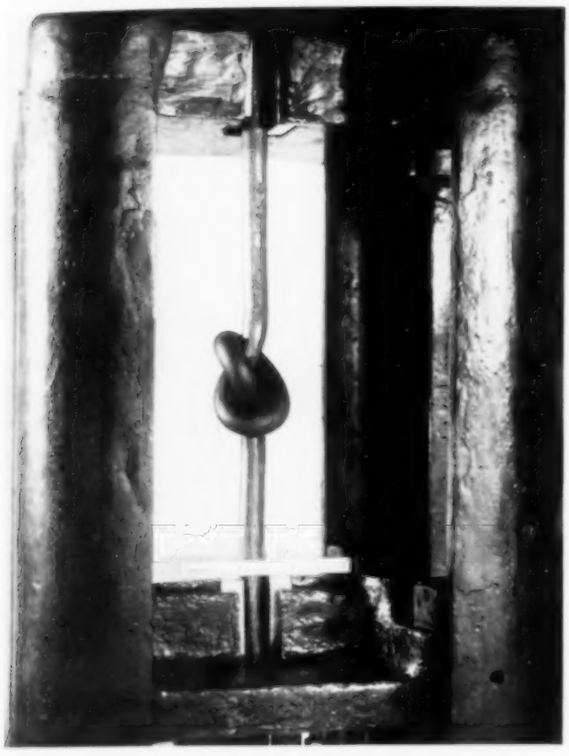
By comparing the properties of Cr-Mn-Si steels with those of other types, it is readily possible to distinguish the contribution of each of the alloying elements to this steel. Silicon increases the yield point and the general ruggedness of the alloy, and at the same time does not reduce the machinability, which frequently results when other hardening elements are added. It also increases the tensile strength somewhat.

However, the manganese content has the greatest effect upon this property, and several investigations in England substantiate the belief that it increases the true elastic limit to a definite and high figure (in contradistinction to "yield point," which, in plain carbon structural steels, appears to give a fictitiously high value of the elasticity). The curves on page 38 show the relationship between carbon, manganese and ultimate strength.

Chromium contributes to the greater strength and proportional ductility and to the ease of heat treatment, when desired. Increases in strength due to small amounts of chromium are also shown on the diagram on page 38. From it can be derived the various combinations of the three elements which will produce steel of a given tensile strength.

Cromansil steels, either as rolled or when heat treated, particularly show greater ductility when compared with the plain manganese steels of the same carbon content and the same ultimate strength. This effect of chromium is even more pronounced in compositions of high ultimate strength, such as those above 100,000 lb.

	Properties of Common Grades, as Rolled								
	Staybolts		1-in. Boiler Plate			Structural Steel			
	Wrought Iron	Cr-Mn-Si	Fire Box Grade	Cr-Mn-Si		Carbon	"Silicon"	Medium Manganese	Cr-Mn-Si
				Longitudinal	Transverse				
Chemical composition									
Carbon	0.04%	0.05	0.20	0.21		0.25	0.35	0.33	0.31
Chromium	–	0.25	–	0.47		–	–	–	0.44
Manganese	0.03%	1.12	0.40	1.17		0.40 to 0.70	0.78	1.63	1.10
Silicon		0.87		0.72			0.27	0.18	0.60
Tensile properties									
Yield point	34,000	54,000	36,000	51,000	51,000	38,000	49,000	59,000	68,000
Ultimate strength	50,000	71,000	60,000	99,000	98,000	65,000	87,000	102,000	108,000
Elongation in 8 in.	34.5 (in 2 in.)	31	29	16	14	24 (in 2 in.)	22	20	25 (in 2 in.)
Reduction of area	41.5	75	55			45	42	43	63
Impact, Izod, ft-lb.	48	64	–	–	25	–	–	–	42
Brinell hardness	–	–		210					220



Cold One-Inch Bar of Chromium-Manganese-Silicon Low Alloy Steel in As-Rolled Condition, Tied Into a Knot to Show Ductility and Toughness

per sq.in. as rolled or when normalized. Addition of chromium also changes somewhat the solidification phenomena, and minimizes segregation in the ingots and castings. No difficulty is had in securing small and uniform grain size in the microstructure, a matter which has been difficult to attain in large sections of medium manganese steel.

Combination of silicon and chromium strengthens the steel without proportionate lowering of the ductility, by means of the formation of chromium silicide. Thus, in a Cr-Mn-Si steel with carbon as low as 0.05%, an ultimate strength of 70,000 lb. per sq.in. is obtained in the as-rolled metal.

With chromium present, highly desirable improvements in both yield point and ultimate strength, as well as superior impact strength, elongation, and reduction of area, are found without going to drastic or expensive heat treatment. The familiar benefit of depth-hardening by chromium will also be noted in the steel.

In fact, with these three alloying metals present in proper proportions, one can obtain with slight increase in cost more desirable physical properties than are found in ordinary carbon structural steels. Silicon is added for strength, soundness, ruggedness, and machinability; manganese for high true elastic limit and toughness; chromium for strength, ductility, and homogeneity.

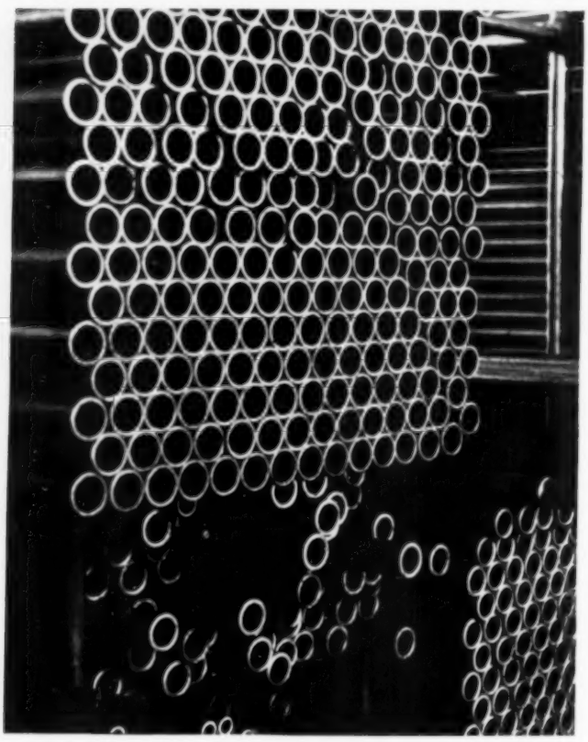
Cromansil steels can be rolled, pierced, and drawn with relatively little increase in effort and cost, and with no fundamental variation from the usual carbon steel practice. Since the forming and shaping of this material is so nearly identical with that of ordinary carbon, medium manganese, silicon, and silicon-manganese steels, a comparison of their physical properties is interesting and is presented in the accompanying table.

True elastic limit of these Cr-Mn-Si steels (the maximum load which can be applied to a specimen and still allow the piece to return to its original dimension after the load has been removed) is found to be about midway between the proportional limit and the drop of the beam. This time-consuming test is seldom made, but there is no reason to suspect that the relationship would be different from the following found for a steel, as rolled, containing C 0.26%, Cr 0.52%, Mn 1.10%, Si 0.75%:

Proportional limit	47,500 lb. per sq.in.
True elastic limit	52,000 lb. per sq.in.
Yield point	59,000 lb. per sq.in.
Ultimate strength	96,000 lb. per sq.in.
Elongation in 2 in.	28%
Reduction of area	62.6%

The extremely desirable physical properties of the Cr-Mn-Si steels in the as-rolled condition noted in the table in comparison with other successful and widely used steels of none or low alloy content indicate many applications where it was heretofore considered too costly to use alloy steels. Ships, bridges, pressure vessels, penstocks, staybolts, and high strength seamless tubing are a few typical examples of the fields in which the substitution of an alloy steel for ordinary structural steel would be of decided advantage.

Large tonnages of the alloy (0.35 to 0.45% carbon, 1.45% manganese and 0.60 to 0.70%



Petroleum Industry Has Needed a High Strength Low Cost Seamless Tube for Casings for Deep Oil and Gas Wells. Over 2,000,000 ft. of pipe made of the new alloy was sold in 1930

chromium with additions of 0.10 to 0.15% vanadium), have been made into castings to meet specifications of 110,000 lb. tensile, 65,000 yield, 18% elongation and 21% reduction of area.

In 1930 over 2,000,000 ft. of oil well casing, weighing approximately 30,000 tons, of this new type of steel was used with most satisfactory results. That this metal can so well provide the service demanded in this field is ample proof that it will go far in providing a high strength, low-alloy material for general structural purposes. Crushing tests, wherein the tubing is flattened entirely to closure without cracks at the extreme bend, show its extreme toughness and ductility.

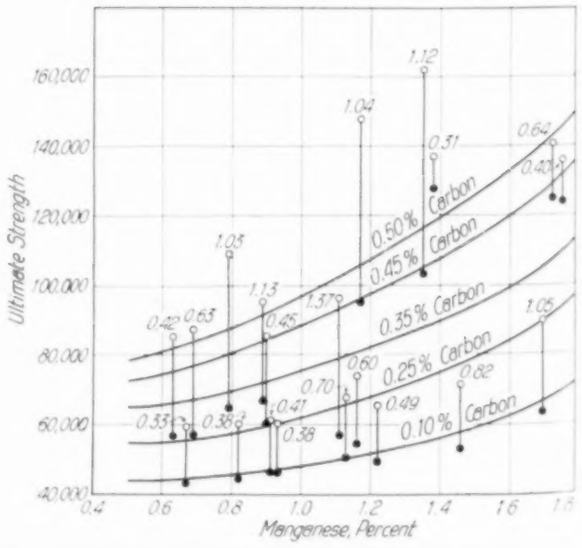
Weldability

The welding of plate, pipe, or other shapes or parts can be done with the usual equipment and normal procedure control for carbon steel of the same shape. With the lower carbon percentages and ordinary weight of plate, no air-hardening effects are usually noted.

Plate containing 0.40 to 0.60% chromium, 1.10 to 1.30% manganese, 0.70 to 0.90% silicon, and approximately 0.20% carbon should show, if properly welded, joints of approximately 94,000 lb. per sq.in. ultimate strength and 20% bend elongation in the as-welded condition. Normalizing the welded plate will increase the bend elongation and ultimate strength by only a few per cent.

With plate heavier than one inch in thickness, the rapid conduction of heat away from the weld may cause the metal in the heat-affected zone immediately adjacent to the weld to become harder and less ductile. Such welds should be normalized after welding in order to secure the maximum combination of desirable physical properties. This is particularly true with steels of a higher carbon content than 0.25%. For high pressure equipment, or for heavy duty engineering structural service where steel of high strength is to be welded, the use of a special high strength alloy welding rod is necessary.

Curves and Black Dots Show Strength of Carbon-Manganese Steels. Open circles show strength of corresponding steel after the noted amount of chromium has been added. All data for steel in as-rolled condition



STRONG TOUGH WELDS MADE RAPIDLY

peening and stress relief improves joint

By Gilbert E. Doan
Assoc. Prof. of Physical Metallurgy
Lehigh University

DUCTILITY of arc welds in steel, the quality in which heretofore they have been most deficient, has been increased more than 100% in the past five years. Likewise, the speed with which the weld is made has been doubled. Strangely enough, knowledge of these developments has been very slow in reaching the attention of those who should be interested.

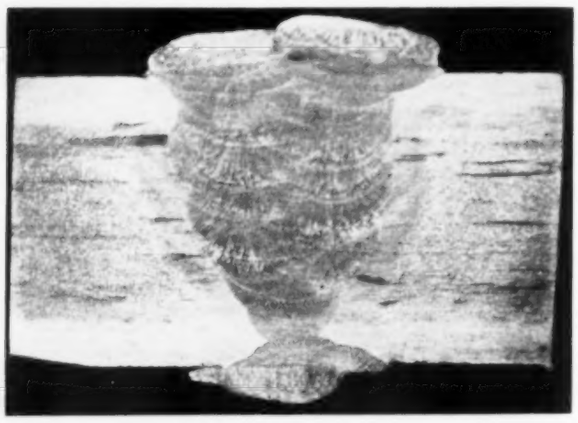
These two important advances, the one in quality and the other in speed of production, have, however, already extended the use of this method of joining steel parts to many applications from which for years it has been barred. For example, 24 steam boilers for the new U.S.N. scout cruisers have been built by the Babcock & Wilcox Co. by this recently improved method, and accepted under specifications drawn up by the manufacturer, the Boiler Code Committee, and the Navy Department. Details of this notable achievement were presented in METAL PROGRESS last March.

Numerous similarly exacting applications of the process, other than marine boilers, but likewise requiring high ductility (as, for instance, the welding of storage tanks, oil refining equipment, and pipe for pipe lines) are now commonly made. Arc welding apparently has surmounted its principal deficiency, and further development of the process, as well as the appreciation of what has already been accomplished, requires that the technique of the process be reduced to a logical basis.

It is the purpose of this review to supply such a foundation as is possible at this early stage of development.

Last month, in METAL PROGRESS, an article was published discussing the influence of atmospheric gases dissolved in the iron as gas or as chemical compound, or suspended in it as insoluble inclusions. It was shown that a prime function of the modern coated electrode is to form a protecting envelope on the hot end of the welding wire, a sheaf of oxygen-expelling gases surrounding the arc, and a blanket of slag over the hot metal in the joint. By such means the embrittling atmospheric gases and their compounds are effectively excluded, with corresponding increase in ductility of the deposited metal.

In the condition as deposited, this weld is considered to be sufficient in quality for many applications. Its ductility can be further improved if desired. For even in this condition of relative soundness and softness the weld is essentially a casting, and, therefore, at least *somewhat* inferior to the rolled and forged parts



Macrograph of Sound Weld in 2-In. Plate Made by Babcock & Wilcox Co. Successive layers are clearly shown with columnar crystals growing from crater bottom

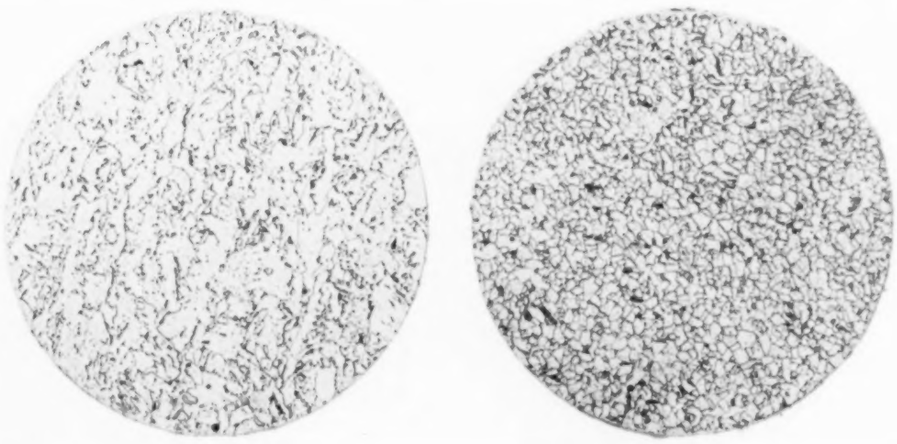
which it joins. Having been cast in a chill mold, the metal has a columnar structure, with the long axes of the crystals perpendicular to the walls of the crater, just as the columnar crystals in a steel ingot are at right angles to the walls of the ingot mold, and for the same reason. These conditions are clearly shown in the accompanying sections kindly furnished by J. C. Hodge of Babcock & Wilcox Co.

But in addition to the coarsely crystalline structure, there may be high internal stresses in a weld, for the "casting" has welded to the walls of the "mold" while it is in the liquid state. When the arc passes, the volume of the "casting" will shrink as it cools, and if the welded parts are immovable, the weld itself must yield. A brittle weld may crack at this stage, being unable to undergo the necessary plastic flow required by the thermal shrinkage. The orientation of the columnar crystals, being radial to the walls of the crater, is also such as to offer a minimum of resistance to such stresses.

If the weld does not crack but yields plastically, as a ductile weld will do, the shrinkage stresses will be partially relieved, at least down to the long-time elastic limit (creep limit) of the metal. But even these residual stresses of considerable magnitude remain thereafter as initial stresses in the welded object. When the stresses of service are added to these internal stresses, the total stress in the weld may pass the ultimate strength of the material and fracture will occur. Or, the gradual relief of these internal stresses in service may warp the object. Evidently, such a weld can be improved by further metallurgical treatment, and this should be done for the most exacting demands, even though with the clean and soft weld made possible by modern coatings, this further treatment is not necessary for all applications.

Complete treatment of the highest quality arc weld includes hammering the weld, followed by annealing. Peening, or hammering the weld with a blunt tool, deforms the ductile metal in the direction required to relieve the shrinkage stresses. It hastens the natural flow, or movements inside the joint, without produc-

Microstructures of the Same Weld, Typical of the Columnar and Fine-Grained Regions, Respectively. Magnification is 100X; etched with 4% nital



ing the sharp notch-effect of a crack. Shrinkage stresses are thus relieved to a considerable extent without leaving a flaw in the weld.

Peening should be done as soon as possible after the weld is made, either by hand or with a pneumatic tool. This hammering operation partially breaks up the undesirable columnar microstructure of the weld — an effect of equal importance to stress relief. A third effect of hammering is that the layer of slag lying on top of the weld is removed, leaving the surface clean to receive subsequent welding.

In welding thin parts, one layer of weld is sufficient. For thicker plates it is necessary to add one or more layers of welding on top of the first bead, each layer being relatively shallow as compared with the total thickness of the joint. Heating of the previously hammered layer of weld by the next one laid on top of it plays a very important part in the refining process. It causes the plastically deformed columnar crystals in the first weld, cold worked by hammering, to recrystallize and to form small, equiaxial crystals. The original ingot structure disappears from this part of the weld, the combined effect of hammering and annealing being roughly equivalent to hot forging.

As a second result of recrystallization, the weld is also left practically free from internal stresses. Ductility is increased by both of these conditions.

In some classes of welding requiring multiple layers the weld is not cold worked as noted above. Heating the first layer by the subsequent one, even in the absence of any hammering, will release in some measure pre-existing internal stresses, by plastic flow of the weld metal at the higher temperature. Slight grain refining may also take place, since the shrinkage stresses alone may have produced slight plastic deformation of the columnar crystals.

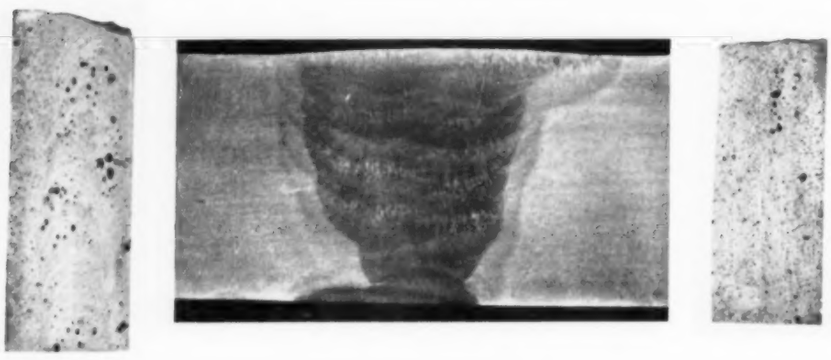
But the complete recrystallization achieved by successive plastic deformation and annealing of each layer must be recognized as contributing something to ductility. If a more complete stress relief is needed, it is desirable to anneal the entire object in a furnace at a dull red heat.

The earlier feeling of engineers that a weld made with bare wire and without any subsequent hammering or annealing was good enough has gradually given way to an appreciation of the high quality that can be obtained in arc welds by additional care and forethought. The modern coated electrode has without question played a leading part in producing this high quality. But the pioneers who appreciated the principles involved and who, with patience and perseverance, adopted methods in accord with those principles, have also made a valuable contribution to the progress of the art.

Plate, ⅝ In. Thick, Welded From Both Sides by Lincoln Electric Co., and Bead Ground Off. In a bending test the outside fiber was elongated 43%. Specimen was pickled to see whether the weld had separated from the plate

How much the ductility is improved by these practices may be understood by comparing the 6 to 12% elongation in 2 in. obtained by the Bureau of Standards in 1920 for bare electrodes with the 20 to 30% elongation (with 60,000 lb. per sq.in. tensile strength, 45,000 yield point, and 50% reduction of area) which may now be obtained from all-weld-metal deposits. (By the term "all-weld-metal" is meant a specimen built up entirely of arc-fused metal and containing no parent metal nor unfused metal. Such a specimen is to be distinguished from one containing foreign metal parts.)

Ductility of the weld metal is shown also in the familiar bend test, in which it is possible to bend an all-weld-metal specimen 180° around a mandrel equal in diameter to its thickness. In this test the outside fibers at the bend are elon-



Compare the Condition of Two Test Pieces of Weld Metal (Made in 1920 at the Bureau of Standards From Bare Electrodes of Iron and Low Carbon Steel) With Cross-Section of Modern Weld Shown in Center. Latter is test piece cut from end of a boiler drum constructed recently for U.S. Navy

gated more than 50%. This test is usually performed on a weld between two steel plates, with the joint at the point of sharpest bend. Elongation of external fibers may readily go above 30%. Compare this also with the bend tests required in the A.S.T.M. specifications for boiler and firebox steel, namely: 180° about a pin equal to the thickness of plates up to 1 in. (which corresponds approximately to an elongation of 50%), and for thicker plates about a pin equal to twice the thickness (corresponding to 33%).

It is interesting also to compare the etched cross-sections of a series of hand-made welds investigated by the Bureau of Standards in 1920 with one produced by the modern process, as shown in the illustration on this page. Weld metal deposited from bare, low carbon electrodes was porous and contained many inclusions, whereas the modern weld is clean and sound. Sections of the porous metal were taken through the median plane of pulled test pieces. The pieces were machined from blocks of arc-fused weld metal built up in tiers. The density of the older hand-made weld is about 7.60, while the modern machine-made weld may reach 7.83 (compared with 7.85 for rolled boiler plate).

Sound weld metal is not to be considered brittle, for it may show Charpy impact values from 20 to 30 ft-lb. with an average of about 25, a figure which compares well with boiler plate which ranges from 8 to 35 ft-lb., (depending on thickness and thermal history) and averages about 20 ft-lb. (The specification of the American Society of Mechanical Engineers does not require this impact test to be made.) Weld metal made with bare electrodes shows from 1 to 8 ft-lb. in this test, the lower ductility doubtless being due both to unsoundness and to aging embrittlement. Charpy test indicates the ability of the metal to resist the expansion of a crack, once it has started in the specimen.

Fatigue tests of the rotating beam type, carried out at the University of Illinois, indicate an endurance limit for the new type welds of about 30,000 lb. per sq.in. — substantially the same as that of a good grade of boiler plate. 18,000 lb. per sq.in. is quoted by Thornton as the endurance limit of bare electrode weld metals in "A Study of Welded Metals Under Fatigue Tests," published in the *Journal* of the American Welding Society for October, 1930.

A summary of the achievements of the arc welder, when the work is done with a properly coated electrode, and under good operating conditions, may be given by citing the welded drums produced for the Navy. The completed drums, together with the test plates, were stress-relieved at a temperature between 1075 and 1150° F. by heating up slowly and holding at the specified temperature for about 1½ hr., and then cooling in a still atmosphere.

Standard tension test pieces cut from all-weld-metal then developed an ultimate strength equal to or greater than the minimum tensile range of the plate used. Bars cut across the joint and bent so the weld was at the sharp bend all elongated at the outside fibers more than 30% before cracks could be noticed. Charpy impact tests gave a minimum of 20 ft-lb. Specific gravity of weld metal was 7.80 or more. Chemical analysis of the weld and of the boiler

plate (made for comparison) was as follows:

	Weld	Plate
Manganese	0.30 to 0.60%	0.30 to 0.50%
Phosphorus, not over	0.04%	0.04%
Sulphur, not over	0.045%	0.04%
Carbon, not over	0.30%	0.25%
Nitrogen, not over	0.020%	0.010%

X-ray photographs of the longitudinal and circumferential joints were made in accordance with the requirements of the A.S.M.E. code, and showed sound, satisfactory metal throughout.

As a final acceptance test, the drums were subjected to a hydrostatic pressure equal to twice the working pressure.

The operating rate in "hot welding" is very much faster than with the old bare electrode process. Electrodes as thick as $\frac{7}{16}$ in. diameter are now commonly used. Owens, in his "Fundamentals of Welding," published in 1923, said then that $\frac{1}{4}$ in. was the usual maximum. With these thicker electrodes higher currents are used, as high as 450 to 750 amp., or more. Arc voltage is as high as 35 to 45, instead of the usual 15 to 20 volts for bare electrodes of the smaller diameters.

Under these conditions, the rate of melting rises from 5 lb. of electrode per hr. to 30 and 35 lb. per hr. The table given herewith has been compiled by a man expert in this field.

In conclusion, "hot welding" with heavily coated electrodes (and with proper mechanical and heat treatment) makes possible welds of good ductility, notch-toughness, and endurance limit, at an operating rate several times higher than that of the bare electrode, and with quite good tensile strength. These results seem to be due essentially to blanketing the metal from the atmosphere and keeping the weld molten long enough for entrapped impurities to float out and escape. Further improvement is possible by grain refinement and stress relief in the weld metal. Still other factors may later be shown to play other important roles, for the development is quite a recent one.

Many new applications of the arc welding process, thus improved and understood, will now be in order.

RATE OF "HOT WELDING" WITH COATED ELECTRODES

Plate Thickness Inches	Arc		Electrode			Groove Width Inches	Lip Thickness Inches
	Amperes	Volts	Diameter Inches	Length Inches	Pounds Melted per hour		
3/8	300	27	5/16	15	5	1/2	1/8
3/4	350	30	5/32	16	7 1/2	3/8	1/8
1	400	33	1/4	18	10	3/4	5/32
1 1/2	500	36	9/32	20	15	7/8	5/32
2	550	38	5/16	22	20	1	5/16
3	600	40	11/32	24	25	1 1/8	5/16
4	700	42	3/8	30	30	1 1/4	7/32
5	750	44	7/16	36	35	1 1/2	1/4

Courtesy Lincoln Electric Company

CONTINUOUS CARBURIZING BY GAS

compact unit installed by Chrysler Corp.

By R. J. Cowan
Metallurgical Engineer
Surface Combustion Corp.
Toledo, Ohio

DESPITE the growth of alloy steels and special means of surface hardening, the ancient art of carburizing steel remains one of the fundamental operations in the manufacture of machine parts. It retains its popularity because it enables the workman to start with a material that can be easily machined, and end with an excessively hard and desirable surface for resisting wear, retaining ductile metal underneath with sufficient strength and shock-resisting properties to stand up to severe duty.

As is well known, most carburizing is done by the time-honored method of packing the steel with carbonaceous materials in suitable containers, covering it in such a way as to prevent infiltration of furnace gases, then raising the temperature to a suitably high point, and holding it there for some hours, depending upon the depth and character of case desired. Carburizing by this means is dependent on a number of factors, many of which arise from the character and uniformity of the compound; great care must therefore be used in handling the compound to obtain satisfactory results. At best, there are still many variables that are hard to control and results that are difficult to explain.

It has been felt for many years that this metallurgical process is too cumbersome and dirty to fit in well with modern manufacturing practice. To those who have studied the matter, it seemed that the desired improvement could be had in a process for carburizing with an externally prepared gaseous atmosphere. Such an atmosphere could be clean, of uniform composition, easily controlled, always fresh and theoretically desirable.

As a matter of fact, a great deal of work has been done on these lines; many valuable contributions have been made that have resulted in installations of considerable commercial importance. The complexity of the possible chemical reactions involved has brought about the ingenious application of mechanical equipment for the control of atmosphere. This is one characteristic of gas carburizing today.

Attention, until now, seems to have been centered upon the development of a series of intermittent or recurring operations whereby the treatment of one lot of steel parts is completed before the work on the next one begins.

This is satisfactory for many purposes, and its successful development was a distinct step forward. However, the trend in mass production is along the line of continuous movement of materials through a factory; hence it seemed necessary that attention should be given to the development of a process that would fit in with these requirements.

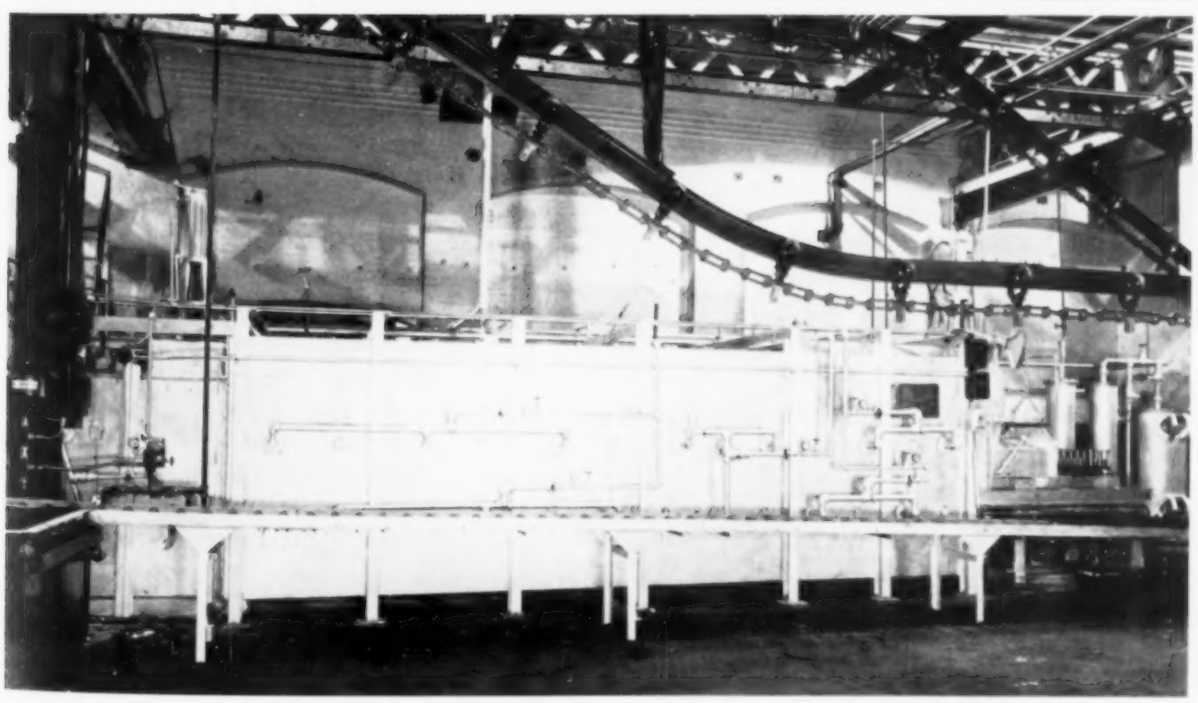
After considerable research work and study in the laboratory of Surface Combustion Corp., such a process has been worked out that has many interesting and attractive features. It is interesting, not only from the theoretical and scientific standpoints, but also because it lends itself so well to modern shop conditions.

A discussion of the gas reactions and other theoretical considerations has been given by the author to the American Institute of Mining & Metallurgical Engineers at the recent Boston meeting of the National Metal Congress (Technical Publication No. 439). The present article will consider the industrial applications, and will present some of the results that have been obtained by repeated tests, mentioning the chemistry of the process briefly in passing.

Essential details of the continuous gas carburizing process may be summarized briefly as follows:

A hydrocarbon gas, such as methane, ethane, propane or butane, is mixed with the products of combustion of a gas-fired furnace, the latter containing from 8 to 10% of carbon dioxide. These mixed gases are dried and introduced into a muffle containing work to be carburized, in such a manner that they will flow through the muffle in the same direction as the work. Rapid diffusion is prevented by suitable baffles throughout the muffle. The work is then moved progressively through three successive reaction zones of the furnace. In the first or preheat zone the hydrocarbon gas begins to break down into its constituents, hydrogen and carbon, the exact temperature depending on the hydrocarbon used, but in any event is below 1450° F., so that the work to be carburized soon becomes covered with a deposit of carbon. Carbon deposits on the surface of steel to be carburized rather than on the walls of the muffle

New Furnace Placed in Production Line Designed to Deliver Continuous Stream of Carburized Parts With Mixture of Gases Produced in Equipment at Right Background



through which it is passed, or the work carriers, since these are made of a certain class of heat-resisting alloys which will not catalyze the gas decomposition to any great extent. The presence of flue gas in this first zone of the furnace serves only as a desirable diluent for the rich carburizing gas.

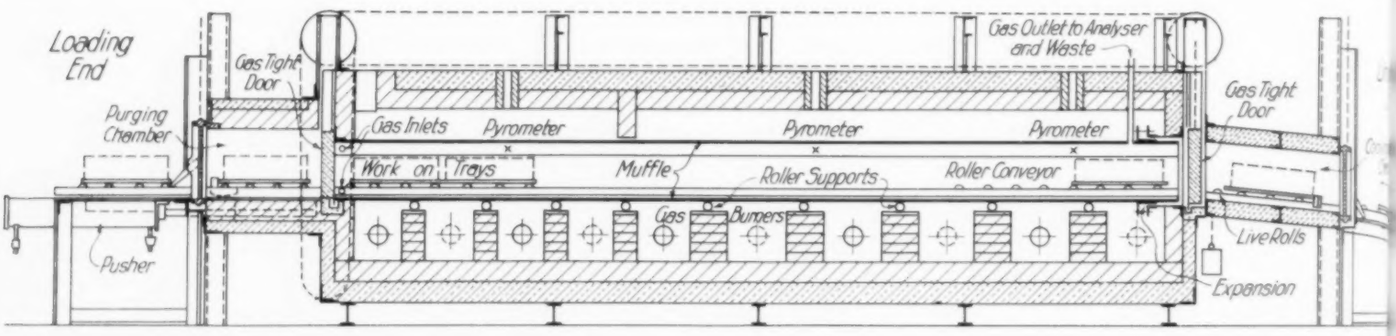
Methane Counteracts Hydrogen

As the work, now covered with carbon, moves along through the furnace it comes into the high temperature or carburization zone at approximately 1650° F., in which the carbon dioxide of the flue gas becomes active. In this zone the carbon dioxide reacts with carbon to form carbon monoxide, in accordance with the reversible chemical reaction $C + CO_2 \rightleftarrows 2CO$. This means that carbon monoxide, which is known to be an active carburizing gas, is being formed progressively by carbon directly in contact with the metal surface to be carburized. It is important to note that in this middle zone there is always present, along with the carbon and its oxides and hydrogen, a certain amount of hydrocarbon gas that has not broken down completely (or at least there remains considerable methane, CH_4, which is the last stage of its decomposition). The presence of this hydrocarbon prevents the decarburization of the metal in the atmosphere, high in hydrogen, that surrounds it in this zone.

After spending the required time in passing through this high-temperature carburizing zone, the work enters the third, or diffusion zone, held at the same temperature. Here, also, there is a simple adjustment between methane and hydrogen and between carbon monoxide and carbon dioxide to produce an "inert" atmosphere, that is to say, one which prevents any decarburization of the exposed steel surfaces. By holding the metal in such an atmosphere, there is brought about a progressive diffusion of carbide from the case inward to the core, so necessary for a satisfactory adherent case.

Apparatus simple in operation and rugged in construction has also been developed. Its general design is shown in the accompanying drawing. It consists of a muffle chamber extending throughout the furnace length, ending at the charging end in a purging chamber, and at the discharging end in a cooling chamber. This discharge chamber can be arranged so it may be held at temperature, prior to quenching the freshly carburized parts without an intermediate reheating. Both of these small chambers are separated from the main body of the muffle by gate valves which make the muffle gas-tight. Doors at opposite ends, leading to the outside, have a machined edge which is held tightly against the slides by a cam or toggle.

Work is carried through on alloy grids or trays of sufficient rigidity to carry the load. The grids ride through the muffle on rails and rollers.



Work Loaded on Trays Is Pushed Slowly Through Muffle, With "Air Locks" on Each End. Carburizing gas enters with cool work and both progress through zones of rising temperature. Gas mixture is controlled by automatic analysis of exhaust at discharge end

the movement being actuated by a suitable pusher. The mixture of carburizing gases is introduced continuously at the correct rate at the charging end of the muffle, both above and below the work, so as to flow concurrent with the work throughout the entire length of the muffle. Spent gases burn at the discharge end.

This furnace is heated by gas burners firing above and below the muffle. Temperature is controlled by automatic regulators and thermocouples placed at three different points in the muffle. A unit of this type will occupy about 60% of the floor space required by a pack furnace of equivalent tonnage.

Furnace Operation

Operation is as follows: A loaded grid is placed in the chamber at the charging end of the furnace. After the outside door is closed this chamber is purged; that is, the air is replaced with flue gas. When the inner doors or valves at both ends of the muffle are raised simultaneously, the pusher shoves the load into the furnace, and (assuming that the muffle has been filled) a corresponding load is pushed out into the cooling or holding chamber. After lowering the inner doors the finished load may be removed when it has cooled sufficiently, or it may be held at the quenching temperature.

Comparing this process with the usual practice of pack carburizing, the following advantages will be observed:

(a) Lower first cost of unit,

(b) No compound handling systems,

(c) Less labor for loading,

(d) Elimination of expensive containers,

(e) Where direct quenching is required, a definite holding zone is provided, thus eliminating labor for reheating operations,

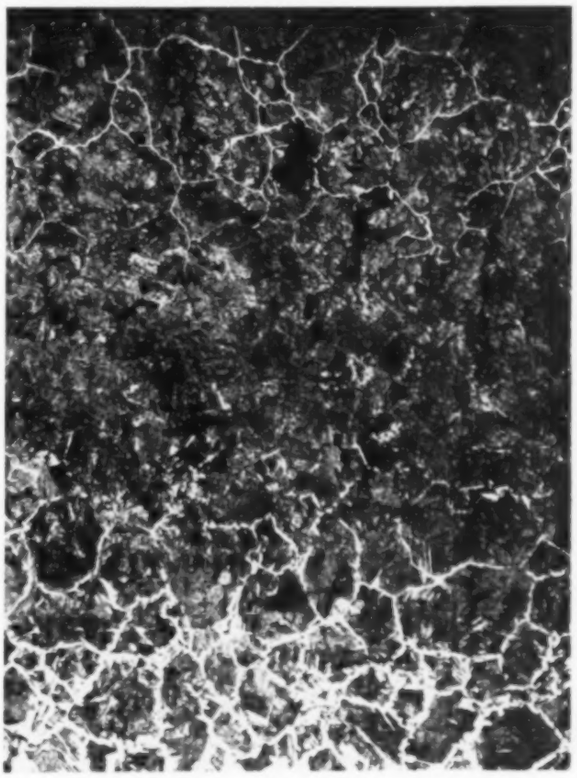
(f) Fuel saving due to reduction of gross materials being heated.

We believe that for the first time in the history of carburizing, this process offers to industry a method of controlling the type of case to be produced on the surface of the steel. This control is exercised by regulating the proportion of hydrocarbon gas and flue gas used for the carburizing mixture. Changes in the relative amount of these two gases are reflected directly in the type of case produced, whether a low carbon hypo-eutectoid case, a higher carbon eutectoid case, or a hyper-eutectoid case with still higher carbon.

We withdraw from the outlet end of the muffle a small amount of gas for analysis that has passed through the carburizing reactions. By means of a special method of analysis for carbon dioxide and methane, made with automatic and recording equipment, the operator knows at all times what the exact carburizing conditions are within the furnace proper, and is able to detect at once any changes that may have taken place due to mechanical difficulties or other causes. This chart is similar to the well-known pyrometer record. Such a record of carburizing conditions taken continuously from the carburizing chamber reveals what is going on and offers a means of control never before realized.

It has therefore been possible to produce

Hyper-eutectoid Case About 0.040 In. Deep in S.A.E. 1020 Steel Made in Production by Continuous Gas Carburizing Furnace. Note gradual transition, zone to zone



finished parts of very fine uniformity, not only within the piece itself, but from piece to piece throughout an extended run. This is illustrated by three micrographs of typical cases produced during a long test on this furnace. Each one of each lot was so nearly like its fellows as to be almost indistinguishable, the only difference noted in depth of case being due to fine grain in the steel, but only amounting to 0.002 in. even from this cause.

Penetration is Rapid

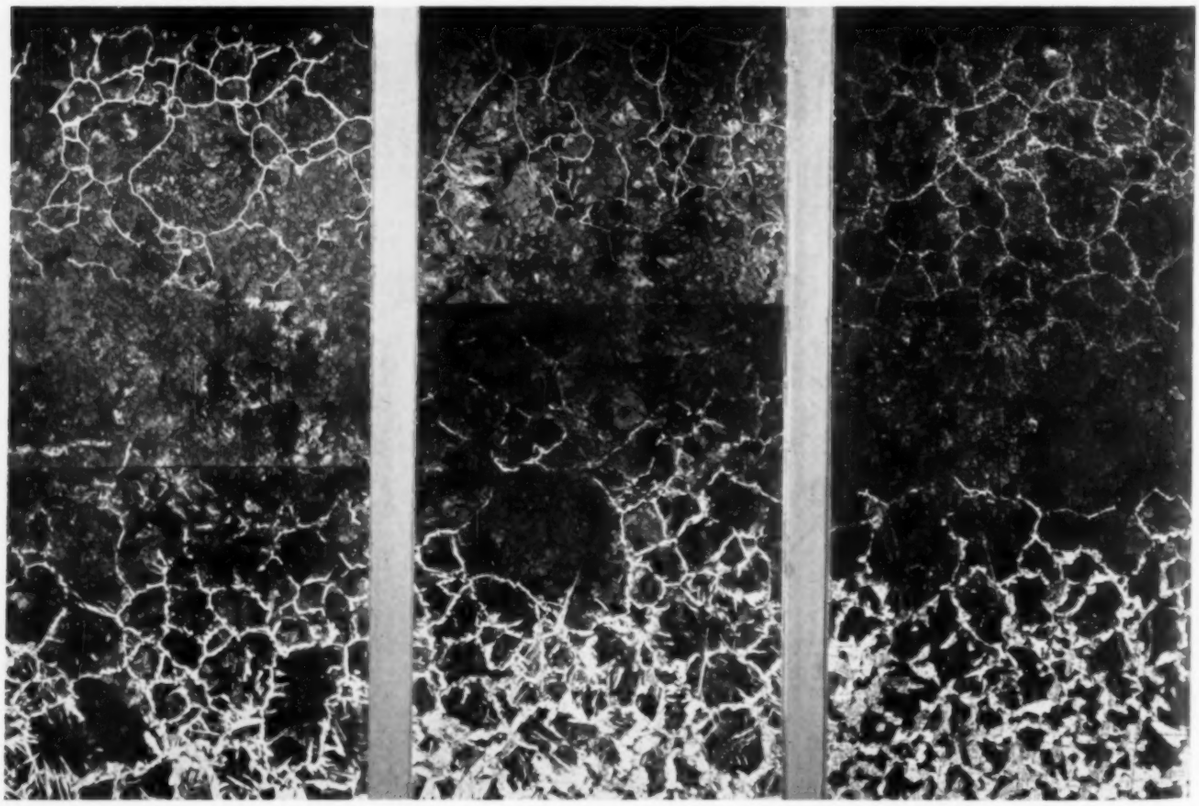
Rate of carburizing is high. We found that a case penetration of 0.045 in. could be obtained in 3 hr. at a temperature of 1675° F. with S.A.E. 2315 steel (about three times the usual carburizing rate of pack carburizing).

Diffusion between case and core has been found to be uniform and gradual, regardless of the amount of carbon in the case, indicating that there is a good bond between the two. The usual sharp line of demarcation, so common where carbon monoxide alone has been used as the carburizing agent, is absent.

Attention must be called also to the fact that the process is clean. By proper regulation of the ratios of the carburizing gases, it is possible to bring the work from the furnace without any free carbon on it, clean and in condition for the next operation. There is no packing of boxes, nor handling of hot, dusty compound, since the carburizing medium is wholly gaseous.

This contribution to the science of carburizing is making a strong appeal to the industry, and one large commercial installation is in operation at the Newcastle plant of Chrysler Corp., and others are under construction. It is hoped that it will prove to be of real assistance in the scientific heat treatment of steel.

Samples Taken at Random From Production of Automotive Parts of S.A.E. 1020 Steel. Case desired: 0.060 in. Compare uniformity, piece to piece, and also compare structure of same part shown on page 47, when controls had been adjusted for somewhat shallower case



HIGH CARBON, HIGH CHROMIUM STAINLESS

heat treated for toughness and strength

By H. T. Morton
and I. A. Rummler
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Ann Arbor, Mich.

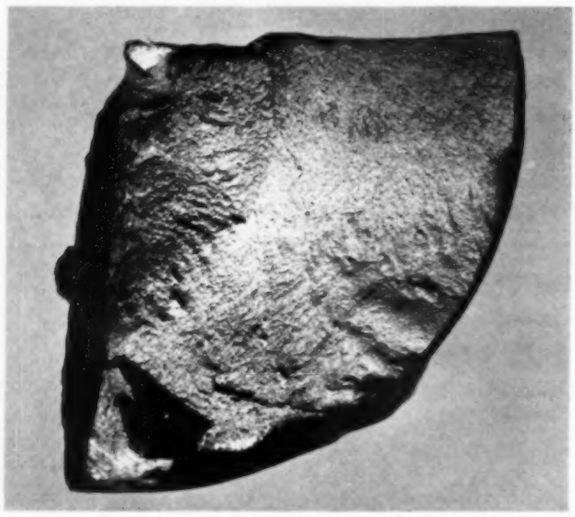
REGARDLESS of the vast quantity of literature that has been published on the subject of stainless steel, one of the oldest of these alloys has been almost neglected. We refer to the high carbon type covered by Armstrong's patent No. 1,322,511 granted in 1919. It contains about 1.0% of carbon with 17.0% of chromium, is capable of retaining a Rockwell hardness of C56 to C60 after quenching and drawing, and is highly resistant to corrosion.

This material has found an important field of usefulness, especially in the oil industry where a hard metal highly resistant to corrosion is needed. As is noted in an article in METAL PROGRESS last month, it is used extensively for pump valves in pumping oil from the wells, through the pipe lines, and about the refineries.

Like other stainless steels, its working at the mill and by the heat treater must be very carefully controlled. The paper last month indicated the importance of correct mill practice and clean, sound steel. This paper will furnish some data on the proper heat treatment and the resulting physical properties. Since balls, valves, and other parts used in the oil industry fail either by erosion due to wear from the sand and solid matter contained in the oil, by corrosion due to attack by acids and chemicals contained in the oil, or by flaking and cracking due to low impact resistance, the development of proper physical properties is absolutely essential.

In order to determine the effect of various heat treatments on high carbon stainless steel, several bars were selected from one heat of the material known to be free from porosity. The analysis of one of these bars gave carbon, 1.10%; chromium, 17.21%; manganese, 0.36%; and silicon, 0.52%. These bars were in the hot rolled annealed condition as received. Photomicrographs on the data sheet, page 53, show a transverse and a longitudinal section of these bars at 500 magnifications. In comparison to ordinary structural and low alloy steels, there is a large quantity of excess carbides, but these represent good structures for this particular stainless steel. (All photomicrographs shown on page 53 were taken of specimens etched in a solution of 10 g. ferric chloride, 30 c.c. hydrochloric acid, and 120 c.c. distilled water.)

This high carbon stainless steel must be handled very carefully during the forging operations. It is best to preheat it at 1450° to



Coarse Overheated Grain in Fracture of Stainless Steel Ball Which Broke in Use. Full Size

1500° F. so as to remove all preliminary strains and get the centers of the bars uniform in temperature.

Its shearing range is very narrow; it has a tendency to tear when too cool or break when too hot. It was found that some temperature above 1900° F., depending upon the size of the bar, gives the best results. Temperatures above 2100° F. cause grain growth, and are on the danger line for burning.

Forging Range

Forging can be carried out at temperatures below the burning point of 2200° F., but must be stopped when the material reaches 1800° F. Below 1850° F. this stainless steel is very hard to work and is liable to develop cold working strains and forging cracks. Two more photomicrographs on page 53 show the microstructures of transverse and longitudinal sections of a ball forging after slow cooling.

Forgings must be slowly cooled. They cannot be set in cold air currents because cooling cracks or fine checks will appear on the surfaces if this stainless steel is cooled rapidly. Sudden chilling, as a quench, will cause the forgings to crack immediately or during subsequent heat treating operations. They should preferably be cooled in pans covered with sil-o-cel or other suitable insulating powder, as this has some spheroidizing effect on the carbides.

Normalize at 1600° F.

To insure that all forging strains and previous strains are removed, the forgings can be normalized. It was found that a moderate rate of heating, holding them at heat until they are soaked through, and cooling in pans covered with suitable insulating powder will have a very beneficial effect. Of course, a regular normalizing furnace is to be preferred wherever it is available.

For this work, a temperature of 1600° F. gives the best results in breaking up the large carbides into smaller spheroidized particles without causing grain growth, and in eliminating any shrinkage or expansion that might occur during subsequent heat treatment.

Slow Hardening Reactions

During the preliminary work, some stainless steel samples 1⅛ in. diameter by ½ in. thick were held at heat for various lengths of time at 1850° F. to compare the effect upon hardness and structure after quenching.

Time at Heat	Rockwell Hardness	Structure
5 min.	59.0	Partially broken up
10 min.	59.5	Partially broken up
15 min.	60.0	Fully broken up
20 min.	60.0	Fully broken up
25 min.	60.0	Grains slightly enlarged

These results indicated that 15 min. at heat before quenching is enough, and this practice was used.

Further to check on the sluggishness imposed by chromium, samples 0.84 in. diameter by 1 in. long were cut from bars of three different 1% carbon steels and placed in a furnace at 1600° F. They were carefully watched through a peephole until they reached the full temperature of the furnace, and this time was recorded as follows: Carbon tool steel with no chromium took 11 min.; a ball steel with 1.1% chromium, 13 min.; and a stainless steel with 17% chromium took 20 min.

These results show that the addition of

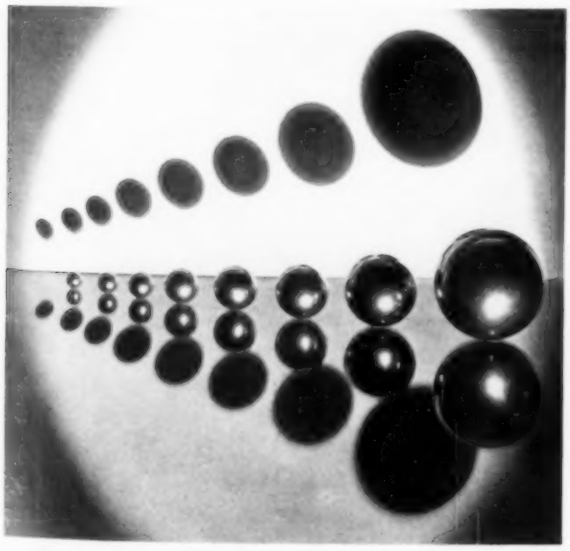
1.1% chromium to the high carbon steel increased the heating time 2 min., or 18%, while an increase of 17% chromium increased the heating time 9 min., or 80%, indicating that stainless steels of high chromium content absorb heat more slowly and should be heated more slowly both before forging and before hardening.

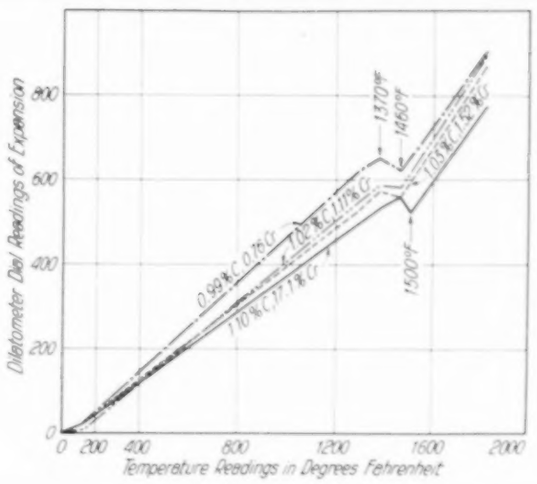
To determine the proper quenching temperature, pieces ½ in. thick were cut from bars 1¼ in. diameter, heated to various temperatures, and quenched in oil. These pieces were then polished, tested for Rockwell hardness, and cut in half for microstructure. Rockwell hardnesses for the quenching temperatures are:

1800° F.	C55 to C58
1850° F.	C56 to C59
1875° F.	C57 to C60
1900° F.	C61 to C63
1925° F.	C59 to C63
1950° F.	C59 to C62

Maximum hardness is reached at 1900° to 1925° F. and an increase in temperature does not increase the hardness. Microstructures, as shown on page 53, of pieces hardened below 1900° contain banded carbides, those hardened at 1900° and higher contain globular carbides, and those hardened above 1925° show grain growth.

The impact tests made at the University of Michigan on specimens hardened at 1850° F. and 1900° F. and not drawn are 0.625 and 0.80 ft-lb. respectively, further indicating the desirability of quenching from 1900° F.



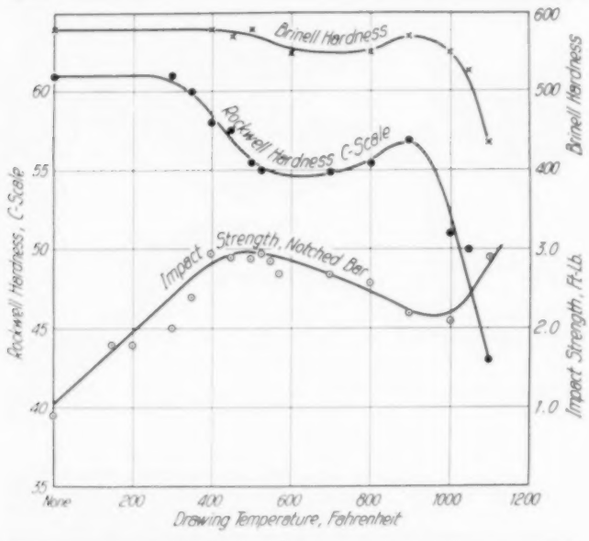


Dilation on Heating of Low and High Chromium Ball Steels. All steels have about 0.35% manganese, 0.015% phosphorus, and 0.015% sulphur

Further work was done for the authors by Dr. Claude L. Clarke, Department of Engineering Research, University of Michigan, using the Rockwell dilatometer for measuring the expansion of steel at elevated temperatures. His curves are plotted on the accompanying chart. The chromium ball bearing steels (chromium from 0.76 to 1.52%) appear to have the same Ac_1 and Ac_3 points. The Ac_1 point of stainless steel (chromium 17.1%) is 87° F. and its Ac_3 point is 43° F. above those for the low chromium steels.

It would thus appear that the carbon content is the determining factor in the *critical* range of stainless steel as of other steels — the chromium merely raises it slightly. But, as shown by the tests of various quenching temperatures, the chromium content does influence the *hardening* range by raising it about 400° F. above the critical range. This elevated hardening range is caused by the greater difficulty in properly dissolving the large number of chromium carbides and iron carbides present; they require higher temperatures and longer soaking. Even slight variations in the temperature or soaking time affect the structure and hardness sufficiently to be readily noticeable.

After hardening, this high carbon stainless



Influence of Drawing Temperature on an Oil Quenched High Carbon, High Chromium Steel. Avoid temperatures between 825 and 1075° F.

steel should be drawn to the required hardness to relieve quenching strains. The curves give Brinell hardness, Rockwell hardness, and impact values obtained by quenching in oil from 1900° F. and drawing at the temperatures shown for 30 min. The Brinell and Rockwell hardness curves resemble those for high speed steel, as they drop slightly between 450 and 800° F., and rise to a high point at 900° F.

Impact Values

Impact values have a slight maximum between 400 and 500° F. and drop off gradually to a minimum at 1000° F., then turn upward, and probably continue to rise to the value of annealed material (4.0 ft-lb.) at higher drawing temperatures. These impact results agree with similar notations by J. A. Mathews, who observed in the course of a symposium on "Developments in Automotive Materials," Detroit regional meeting, A.S.T.M., 1930, that "the impact resistance of stainless iron improves gradually with tempering temperatures up to about 800° F. From 800° to 1000° F. is a range in which the impact resistance falls off materially and it is well to avoid this particular range of tempering. There is another reason for doing so; namely, that within this range hardness changes are very rapid. With slight changes in temperature it would be difficult to control uniform hardness and physical properties within this range.

"Tempering from about 1100° to 1250° F. gives very excellent physical properties, including high impact resistance, and the product is machinable when so tempered. In other words, the heat treating and tempering may be done first and the machining afterward. It has not been emphasized sufficiently that stainless iron is subject to temper brittleness when slowly cooled from the range of 1100° to 1250° F. When tempered within this range and slow-cooled in the furnace, it is not unusual to find impact resistance from one-third to one-fourth of what it would be if the iron had been cooled from the tempering operation by quenching. It might be further stated that, in tempering operations where high strength is desired, such as those below 800° F., it is unimportant whether the material is cooled slowly or rapidly for this treatment.

"To summarize — after tempering up to 800° F. the cooling may be slow or rapid. Tempering between 800° and 1100° F. should generally be avoided, particularly if the part is subject to impact. Tempering above 1100° F. should be followed by quick cooling of the tempered parts."

A similar brittle range in the vicinity of 1300° F. was observed on 18% chromium, 8% nickel stainless iron by H. H. Lester in *Transactions*, A.S.S.T., November, 1929.

Specimens used in determining the impact values shown on the chart were $\frac{3}{8}$ in. wide by $\frac{1}{4}$ in. thick by 2 in. long with a square notch cut in them 1/32 in. wide and deep. They were broken on an Olsen 100-lb. impact testing machine.

To summarize: This stainless steel can be drawn at temperatures below 800° F. and either quenched or slowly cooled. If drawing temperatures above 1100° F. are used, the parts must be quenched. Parts drawn between 825° and 1075° F. are brittle, and this range should be avoided.

When properly handled at the mill and by the manufacturer, this 1% C, 17% Cr steel gives good service.

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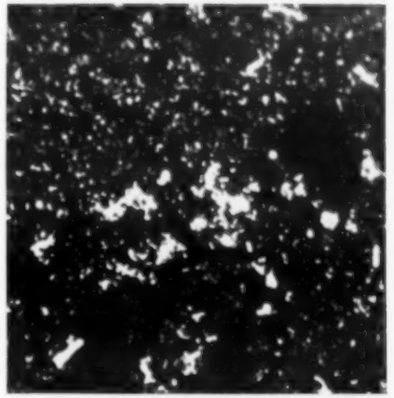
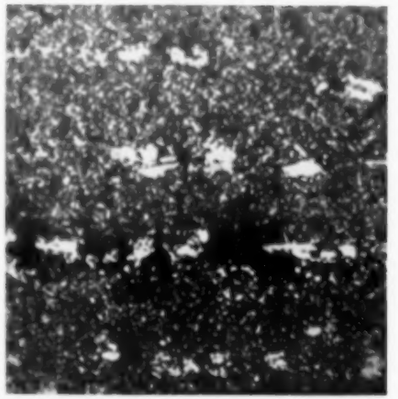
Excess Carbides in 1.1% C, 17.2% Cr Stainless Steel

Magnifications 500 Diameters Etchant: 10 g. $FeCl_3$, 30 c.c. HCl, 120 c.c. H_2O



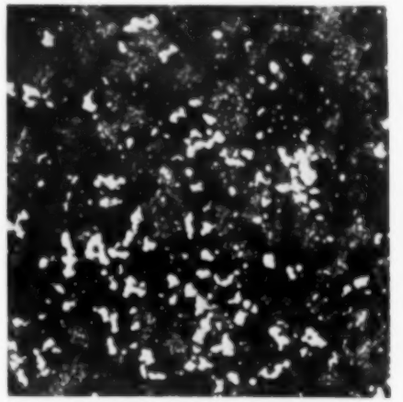
Transverse Section



Longitudinal Section

Segregated Carbides in Bands Plainly Evident

Hot Rolled Annealed Bar



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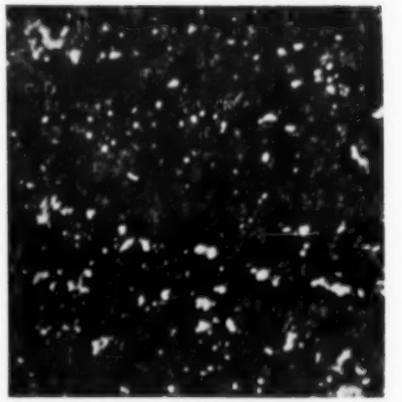
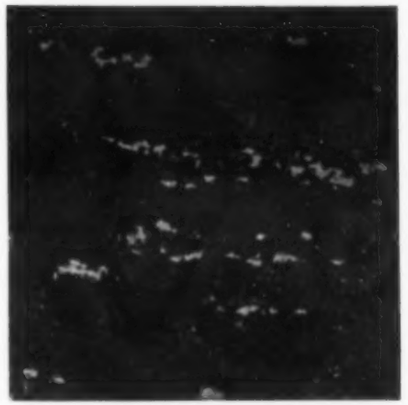


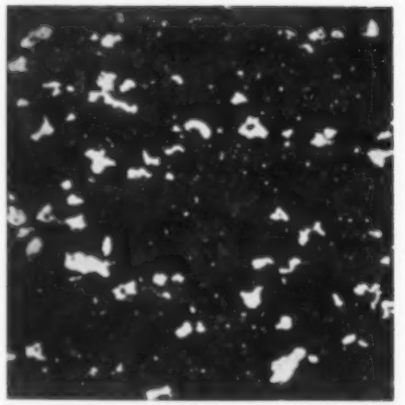
Longitudinal Section

Carbide Bands in Bar Partly Dispersed

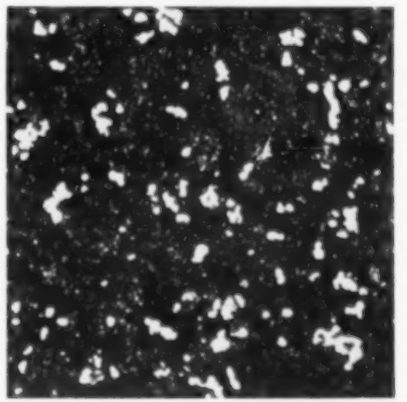
Forged Ball, Slowly Cooled



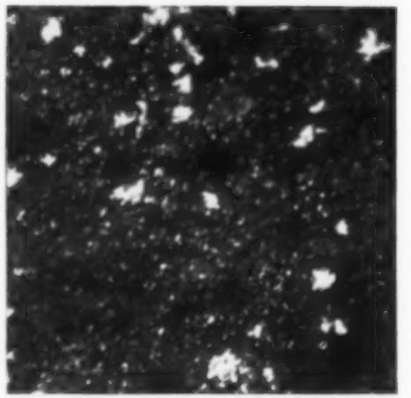
Oil Quenched From 1800° F.
Note banded fragments of carbide



Oil Quenched From 1900° F.
Carbides broken up and not banded



Oil Quenched From 1900° F.
Drawn 30 Min. at 550° F.



Oil Quenched From 1900° F.
Drawn 30 Min. at 900° F.

Drawing temperatures have slight effect on size and distribution of carbide

Longitudinal Structures of Forged and Heat Treated Balls

Photomicrographs by I. A. Rummler, Hoover Steel Ball Co., Ann Arbor, Mich.

Photo by John P. Mudd for The Midvale Co.

The Melters Call Her "Mary Anne"

. . . EDITORIAL . . .

Amateur Theorists

RECENTLY, an earnest teacher in an "opportunity school" (really a trade school for unemployed) sent out letters to well-known personages in the welding industry asking for an opinion as to whether he should include such things as chemistry, physics, metallurgy, metallography, cost accounting, and descriptive geometry in his course of instruction. It ought to have been evident to him that nearly all of his prospective students will be unprepared mentally to absorb anything of value from these advanced subjects, and their main object will be to achieve the necessary manual dexterity in the shortest possible time. They will have to become workmen or operators first; only a few will develop latent supervisory ability. The rest of them will do as they are told, and their foremen will make the necessary layouts and diagnose any troubles which require knowledge of the allied sciences.

All can recall some instance where a little knowledge of theory has led to an erroneous interpretation of a set of facts. It occurs frequently enough to warrant the saying: "The practical man and the scientist both argue from theory, but the practical man's conclusion is wrong."

An amusing instance of this is being told on the Coast, at the expense of a "metallurgist" of one of the eastern producers of 18-8. This expert pointed out to a prospective customer that alloys of this type are composed of three metals, iron, chromium, and nickel, each having different coefficients of expansion. He further remarked that when such an alloy is heated the iron expands at one rate, the chromium at another, and the nickel at yet another, so the alloy is working internally against itself and just "tears itself to pieces." He believed that any such combination of alloys is bound to fail in high temperature service.

This is a refreshing change from the prevalent theory that embrittlement and selective corrosion are promoted by the precipitation of carbides at the surfaces of the metallic grains forming these austenitic alloys! Is it possible that the many investigators who are earnestly seeking some stabilizer for carbide in solid solution are looking in the wrong direction?

Secret Processes Are Good to Avoid

WHY editors do not like plants which are guarding "secret processes" should be very evident. Publicity and secrecy are antithetical words and antagonistic aims. Often enough the manager of a plant operating behind closed doors may be a pleasant companion, or have a generous purse for charity — but this only emphasizes the anti-social and miserly aspects of his business.

For the operation of a secret process advertises the operator's belief that he is self-sufficient, he owes nothing to the industry, art, or science. If he owes nothing, he has taken nothing from it.

Yet it is strange that anyone should presume to believe that he is beholden to no one for the technical operations in his manufacturing plant. How far could even the cleverest mechanic or inventor get if he were to cast aside all the scientific information accumulated by numberless investigators in the last century and *published* for the general good? How far could any plant get without using freely the

appropriate machines, metals, and substances produced by the labor of others?

How few are they who do not actually employ competent technicians and engineers, educated by others and possessing a store of knowledge derived from the work of others? In fact, unless a constant inflow of new brains is bought, the "secret" process is rapidly outdistanced by its outside competitors. The fence that keeps old ideas in also keeps new ideas out. So it usually transpires that by the time the cat is finally out of the bag, it is found to be a common Tom, more or less mangy, that everybody has seen on back fences for years!

One further aspect of the problem is seldom appreciated. It relates to the men who accept employment. A hypothetical instance can be described, wherein Elmer Zilch, a promising young Ph.D., accepts employment with the Goodfire Rubber Co. He signs a document agreeing to keep under his hat the processes he may invent, supervise, or observe.

Within ten years he has worked up to be manager of the department which makes rubber tires from sagebrush (a very profitable operation), but unfortunately his wife's health is none too good and the doctor orders a change of climate — Southern California preferred. So he finally moves out there, and is quickly approached by the Richstone Tire Co., anxious to develop commercially their 1,000,000 acres of prime sagebrush, and sell to the passing motorists at a nice profit.

Well, Elmer knows how to do it, and the salary is very attractive (in fact, necessary) but he had better watch his step! As soon as the old Goodfire gang learns that Richstone is taking business away from them with their "Yucca Tread Special," Elmer and his new bosses will find an expensive law suit deposited on their doorsteps, and they will spend a large part of the next few months trying to convince Judge Capias that they have not stolen property (secrets) belonging to the Goodfire company and are using it to the rightful owner's detriment, and should not therefore cease and desist and render an accounting.

This fable is more fact than imagination. It is true that successful service and experience in plants having the open door can be capitalized by the salaried man and is a valuable asset when he comes to look for another job. It is also true that similar service on a secret process is no asset at all, in fact, may make him unemployable by any firm which could use his store of information and experience.

Solidus; Liquidus; Solvus

INVESTIGATORS who are instinctively precise in their measurements are frequently very careless in their use of words. Terminology in advanced metallography is therefore worse confused than in almost any other science.

For instance, three definite conditions in metal, inherited from as many causes, are commonly and indiscriminately called "fiber." Neither is there any consistency in the use of the cumbrous phrases representing the phenomena of blue brittleness and aging of alloys. We have "quench aging," "duralumin type aging or hardening," and "seasoning," and we have "over-strain aging," "deformation aging" and "cold work aging." The science needs another Henry Marion Howe, who knew how to manufacture a correct word, and who, because he was a great teacher and prolific writer, used these new words constantly, led other people to use them and so established them firmly in the language.

Of course, usage establishes the word, good or bad; slang or spuriously coined words arrive in dictionaries and in belles lettres after enough people use them for a long enough time. Witness the word "sonim" — about as artificial a word as one could imagine, yet everybody now understands what is meant when somebody else uses it. Or if you want words of more elegant sound, sponsored by eminent literati, how about "am't I" (for "am I not") or "brunch" (for a combination breakfast-lunch)?

It is well for a proposed word to have an

honest linguistic parentage. Such a word is "solvus," proposed by Dr. Mehl for the curve of solid solubility — the curve of such importance in interpreting aging or seasoning phenomena. Constitutional diagrams already have other lines with accepted names, such as liquidus (where the alloy is just melted) and solidus (where it is just solidified). Solvus (where the solid solution is just saturated) is certainly a worthy addition.

Now if everybody will use it, the job is done! Practice it on your tongue.

Bad Guesses

WEATHER forecasters frequently have difficulty in predicting whether it will snow during the afternoon. Economists and their guesses about business next quarter or next year are much more discredited. Even statisticians should be wary about prophesying the production of metal 10, 20, or 30 years ahead.

Nevertheless, some estimate of future trends is a necessary foundation for intelligent planning, and the only reasonable basis of such estimates is a study of the history of the industry and its relation to other events such as political movements, wars, and advances in applied science.

Such predictions can and do go sadly wrong, because the prophet fails to appraise properly the importance and influence of current events. Take, as an instance, estimates of world production of pig iron, a basic commodity which has enjoyed some popularity as an index of general business, and about which adequate statistics are available. An observer in 1890, looking backward for 40 years, would have noted a slow but sure acceleration in the blast furnace output, year by year. From a smooth curve fitting his data, extrapolated for 20 years, he would conclude that in 1910 the world would produce about 45 million tons of iron. As a matter of fact, the unforeseen development of a satisfactory gas engine occurred during that generation, and the make was actually 65 million gross tons.

Sir Robert Hadfield tried his hand at prophecy in 1905, and predicted that the world's consumption (due to an expanding market for machinery in backward areas) should continue to increase at the same rate it had during the preceding 30 years; that is, slightly over a million tons yearly. He was much under the actual mark for several years; the accelerating tempo of the mechanical revolution was responsible for a 1913 production of about 75,000,000 gross tons (easily 20,000,000 above Sir Robert's prediction). Then came the War, which dislocated everything; during the post-war slump the pig iron output was lower than the predicted curve for four years, but then shot dizzily upward.

Re-examination of the plotted statistics in 1928 indicated that since the slump of 1921 the actual line could be approximated by the pre-war trend line, moved sidewise 12 years. This represented a hypothetical set-back due to the War — an assumption which then appeared reasonable — and, as events proved, such a dislocated curve did call for somewhat less than the actual production during 1928 and 1929 of 87 million and 97 million gross tons respectively.

Then came the world-wide industrial collapse, and production dropped like a plummet, amounting to 79 million gross tons in 1930 and only 56 million in 1931. The incurable optimists will observe that the ragged peaks and valleys of the production curve (pre-war expansion, post-war slump, recovery during the 1920's, and current depression) straddle Sir Robert's forecast fairly evenly. We are now as far below it as 1929 was above. Whether that means anything or not about what is going to happen in 1932 is doubtful.

Internationalists hint darkly that the War is not yet over, and if they are right the correct "recovery curve" should have been moved sidewise much more than 12 years. Whether one believes that 1932 will go on down to the 1921 nadir of 38 million or whether we are due for a turn depends upon the causes of the 1930 panic, and how soon they can be cured. These causes and cures — well, accept the opinion of your favorite theorist!

ELINVAR HAIRSPRINGS FOR WATCHES

a triumph for metallurgy and mechanics

By G. E. Shubrooks
Chief Chemist
Hamilton Watch Co.
Lancaster, Pa.

SATISFACTION is accorded no place in the vocabulary of the scientist. If research workers should ever reach the point where they were satisfied with discoveries already made, science would cease being a living, growing study and become a closed record of the past!

Because of this driving desire to dig deeper and deeper into nature's secrets, science keeps invention on the move. Industry is prone to lapse into satisfaction and willingness to let well enough alone, once a mechanism has reached a certain stage of usefulness and dependability where it can be standardized.

Thus it has been in the making of watches — those tiny measuring instruments that are so essential to the metallurgist, the chemist, the research man. Accuracy is required by scientists and experimenters in general and desired by a large proportion of all citizens. Before the original thirteen American colonies had been joined into a single nation, the *design* of a watch had been fairly well standardized. It was tacitly taken for granted that improvements must come from greater perfection in manufacture rather than from any fundamental departure in design.

It remained for Dr. Charles Edouard Guillaume, a great physicist (who also knows much about watches, both scientifically and mechanically, and is besides a metallurgist of no mean ability), to explode this assumption and show the watch technician a way to improve time-measuring and other precision instruments. These developments came from a special application of high nickel-iron alloys — a series of alloys which had been known to possess interesting and valuable properties since Faraday and Stodart's investigations in 1822.

Systematic study of these nickel steels did not occur, however, until the decade 1890 to 1900, when British, French, and American metallurgists used them for armor plate and cannon. During this time some standards of length were made of one of the high nickel alloys, and on calibration it was found that it had a coefficient of expansion greater than either of its constituents, nickel or iron. Here is where scientific curiosity entered. It was a matter which had not the slightest interest to the army and naval authorities interested in improving ordnance, but to the physicist Guillaume at the International Bureau of Weights and Measures it was something that demanded explanation. So he

convinced the steel works of Commentry-Fourchambault that an elaborate study of the entire iron-nickel system should be made.

One alloy, containing about 36% nickel, was especially noteworthy, since it remained invariable in length during ordinary atmospheric changes in temperature, and consequently could profitably be used for clock pendulums, surveyor's tapes, and standards of length. This was called "invar" ("nilex" in England). Another low carbon alloy with 46% nickel has almost the same thermal expansion as glass, and was quickly substituted for platinum for lead-in wires through glass seals to incandescent light bulbs. A third and more complex alloy was found whose modulus of elasticity is constant — this is "elinvar," a material which is suitable for precision springs — hairsprings of fine watches, for instance.

For these extensive studies and the development of these useful new alloys, Dr. Guillaume was awarded the Nobel prize in physics. Investigators in many lands have followed his lead. Most notable results have been achieved with nickel-iron alloys containing about 80% nickel, called "permalloy" from its unique magnetic properties.

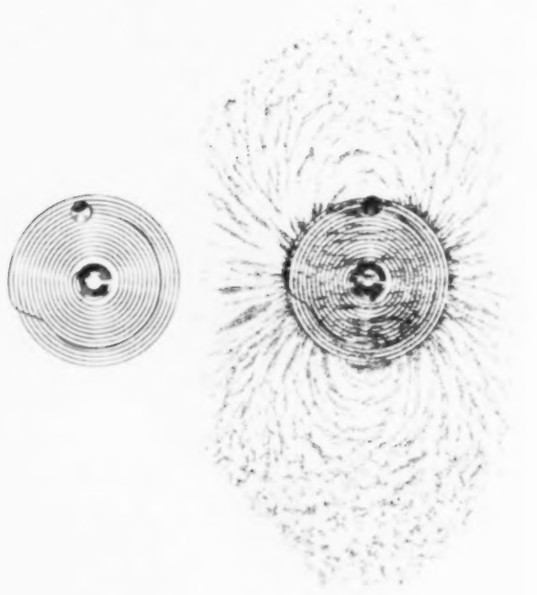
But this is not the place to consider all these interesting developments. They are cited to prove the point — if proof be needed — that researches into "pure science" have again produced results of far-reaching importance to industry. In this country, the Hamilton Watch Co. and its associate, the Illinois Watch Co., have acquired the franchise for the use of elinvar hairsprings in watches and other precision instruments. The name is significant of the quality which identifies it — constant elasticity throughout a wide temperature range — and is derived from the first syllables of elasticity and invariable. Most suitable alloys fall within the following range:

Nickel	33 to 35%
Iron	61 to 53%
Chromium	4 to 5%
Tungsten	1 to 3%
Manganese	0.5 to 2%
Silicon	0.5 to 2%
Carbon	0.5 to 2%

The effect of cold work and heat treatment on the elastic properties has been given close attention, and would itself be a story of considerable technical interest, especially since the part to be formed weighs so little that 13,000 are required for a pound. However, the present aim is to indicate how the new alloy has enabled us to build greater reliability into our timepieces.

For its size and weight, the hairspring of a watch is perhaps unequalled in importance, when measured by service rendered, by any other mechanical detail. It oscillates the balance wheel 5 times every 2 sec. — 5 half-swings or beats per sec., 18,000 beats per hr., 432,000 per day. During a year the little balance wheel rim of a medium-sized watch travels a distance equivalent to 3700 miles!

A brief history of the hairspring would be



A Steel Hairspring and One of Elinvar After Passing Through Same Magnetic Field. Steel filings show magnetic lines. View enlarged somewhat

interesting. Previous to its invention a short bristle was used for the function now performed by the hairspring in a watch mechanism. In the latter half of the 17th century, Robert Hooke (known to all students of physics for "Hooke's Law" that the stretch on a wire is proportional to the load which is hung from it) experimented with a straight flat spring to replace the pig bristle then employed for the purpose.

A little later two watchmakers independently began the development of spirally coiled hairsprings. They were Jean de Hautefeuille and Christian Huygens. Their springs were later improved upon by being made smaller in width, but of greater length and with more turns. Today, 250 years later, hairsprings have about 15 coils.

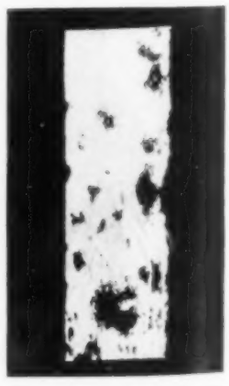
Watch hairsprings are wound in a flat spiral. The type now almost universally used is arranged with the outer end turned up and over the coils where it can be threaded between the regulator pins and then fastened to a stud. This stud is the fixed end; it is held into the upper plate with a screw. This form of construction was invented late in the 18th century by Abraham Louis Breguet, but its full value was not realized until some years after Breguet's death when an exhaustive study of the whole matter of timing a watch was made by the French engineer Phillips.

The chief benefit of the "overcoil" is to insure that the center of gravity of the spring coincides with the center of gravity of the balance wheel. Lacking this feature, the spring would exert pressure laterally on the balance staff, and not only wear the balance staff pivots, but interfere with the uniformity of the oscillations of the balance wheel, thus affecting the rate of the watch.

One needs to observe the regular and even spreading and closing of the coils of a well-poised hairspring to appreciate the efficacy and the value of this little feature of hairspring construction.

To properly appraise the value of elinvar, one must know that its use as a hairspring material makes possible the first radical departure in watch construction since 1766. In that year Pierre Le Roy invented the bimetallic cut-rim balance wheel to compensate for the variations in hairspring elasticity due to temperature changes. A few facts in elementary physics or strength of materials will make this plain.

Hairsprings of yesterday were made of high grade carbon steel wire. It is the same class of material that Robert Hooke used to determine by experiment that the strain or deformation per unit length in a wire is proportional to the stress or load per unit of cross-sectional area. This proportional ratio is known as Young's modulus of elasticity; in steel this modulus is ordinarily taken to be 30,000,000, and this



Rust Spots on Steel Hairspring Cause Serious Variations in Timing Rates. Magnification 75 diameters

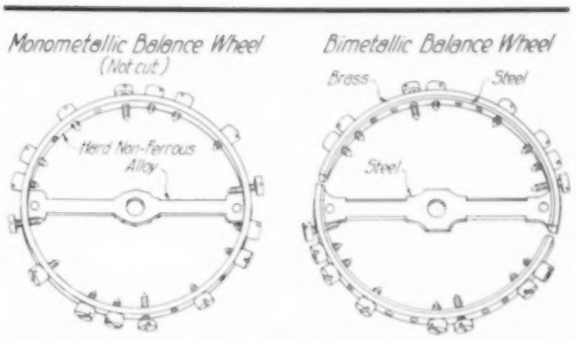
ratio remains constant up to a fairly high unit load; beyond that load plastic flow and permanent set will occur. If any load less than this elastic limit is imposed and then released, the metal will return to its original length.

Unfortunately for the old watchmakers, this modulus of elasticity for carbon steel varies slightly but definitely with temperature. And since the push and pull exerted by a vibrating spiral spring is proportional to the modulus, it resulted that even the best of the steel hairsprings would be a little stronger on a cool morning than later in the day when the temperature becomes milder. Changes in the measured ratio might appear negligible to the uninitiated but the thermoelastic coefficient of carbon steel is such that, without a compensating device, a watch would gain or lose at the rate of 5 to 7 sec. a day for each Fahrenheit degree change in temperature.

In other words, the slight weakening of the hairspring by mild heat or its strengthening by cold would tend to slow down or to speed up the oscillations of the balance wheel were there not a means of counteracting these effects of temperature variation.

Le Roy's invention did this by providing means whereby the circumference of the balance wheel (and therefore the energy required to stop and start it) is enlarged or reduced concurrently with the increase or decrease of hairspring elasticity as temperature rises or falls. The rim of such a compensating balance wheel is composed of a hoop of brass (on the outside) and one of steel (on the inside) fused together. The arm is also made of steel, integral with the inner part of the rim.

Cuts at two points in the rim, adjacent to either end of the arm, divide the rim into two segments whose outer ends are free to move, and do move, of course, as temperature variations cause expansion or contraction. As brass has a higher coefficient of expansion than steel, these free ends of the rim segments are pushed in toward the center when temperature rises. This reduces the periphery and thus decreases the lever arm of the weight to be moved by the hairspring, which, in turn, has been weakened by the loss of elasticity through the same temperature change. Proper temperature compensation would require an exact equality of these two changes at all ordinary degrees of heat or cold.



Comparative Construction of Bimetallic Balance Wheel and Modern Wheel Made of a Single Alloy

Studs in the balance wheel rim are small screws which can be shifted from one position in the rim to another, and are used to establish the proper moment of inertia of the rotating member, produce the proper "period" in the balance unit, and control the poise.

Heretofore, a cut-rim bimetallic balance wheel has usually been considered an essential feature of a high grade watch, only cheap watches being made with a solid, non-compensating balance. But as an elinvar spring eliminates the need for a compensating device, this newer type of hairspring is used with a balance wheel having a solid rim and being constructed of a non-ferrous alloy.

A meno-metallic, uncut balance wheel is, of course, more stable and may be so mounted on the balance staff that both may be removed as a unit. Thus, any disturbance of adjustments is avoided during cleaning or minor repair.

The metal used in this balance wheel is unaffected by surrounding magnetic fields; neither can the high nickel alloy in an elinvar hairspring be permanently magnetized. This combination creates an advantage of great importance to those who must work near electrical apparatus or who happen to come close to strong magnetic fields, a frequent possibility in this age of many diversified applications of electric power.

It is known that a vibrating assembly should only be influenced by the potential energy which is stored in the spring which drives it. A system

Instrument for Adjusting the Vibrating Rate of Hairsprings. Balance wheel permanently attached to the spring is rotated and adjusted until it vibrates in step with the master balance arm in the base of the instrument

of this type should not be influenced by outside forces. Magnetism is the greatest disturbing force because it throws the balance "out of poise" and produces very erratic timing, or even stops the mechanism entirely.

In view of the great number of fields of magnetic force in industry which workmen contact, it will not be surprising to you that this is so important. The Hamilton Watch Co. has established a reputation for "the watch of railroad accuracy," and because of the increased use of electricity, it has anticipated a need of the railroad by producing a watch which will function properly and keep precise time, despite exposure to strong magnetic fields. Extensive tests have revealed that an elinvar-equipped watch will resume running as soon as withdrawn from a magnetic field of a strength as high as 3600 lines per in., far higher than encountered in the vicinity of most electrical equipment.

Tests for Magnetization

Before elinvar watches were put on sale, the Hamilton and Illinois companies conducted experimental research over a period of five years, which included very severe tests on this matter of magnetization.

As an example, ten watches of two grades, each with bimetallic balances and conventional carbon steel hairsprings, were compared and tested with ten elinvar-equipped watches of the same grades. Aside from the difference in the hairspring and balance, corresponding watches in the one group were of identical construction with those in the other.

To indicate how such a test is made it might be said that these two groups of watches, 20 in all, were first given a two-day test in each of five positions ("12 up," "3 up," "9 up," "dial up," and "dial down") in three different temperatures (68°, 41°, and 95° F.). These tests were made with the watches in normal condition; that is, before being exposed to a magnetic field.

As shown by the accompanying tabulation, the average variation in the five positions was 9.0 sec. per day for the steel spring watches and 8.7 sec. per day for the elinvar watches. Average variation in the three temperatures was 3.9 sec. per day for the steel spring watches and 3.2 sec. per day for the elinvar watches. Thus, it was proven that the two groups of watches normally would be equivalent in accuracy.

Lastly, a two-day test was made in the "12 up" position, used at the very start of the test, to show how accurately these watches repeated their original time after 16 days of running in

INFLUENCE OF MAGNETIC FIELD ON ACCURACY OF FINE WATCHES

	Not Magnetized	After Magnetizing in Field of Strength Shown		
		36 lines	360 lines	3600 lines
Watches with Steel Hairsprings and Bimetallic Balances				
Average variation in rate, 5 positions	9.0	10.2	122.3	Stops
Average variation in rate, 3 temperatures	3.9	4.3	48.7	Stops
Average recovery	5.0	1.5	92.0	Stops
Watches with Elinvar Hairsprings and Monometallic Balances				
Average variation in rate, 5 positions	8.7	10.5	10.0	9.7
Average variation in rate, 3 temperatures	3.2	3.1	2.9	4.0
Average recovery	1.8	1.1	0.8	1.8

various positions and temperatures. The average variation between the first and last test is called "recovery," and is listed on the third line of the tables; it amounted to 5.0 sec. per day for the steel spring watches and 1.8 sec. per day for the elinvar watches.

Afterwards the same watches were consecutively exposed to direct current magnetic fields of approximately 36 lines, 360 lines, and 3600 lines per sq.in., respectively, by placing the watches in the center of a large air core solenoid, moving them about and slowly withdrawing them from the field.

After each of the above exposures, each watch was again timed in five positions and three temperatures; and finally the test was repeated in the "12 up" position in a temperature of 68° F., to see how accurately they repeated their original time after magnetization. The results are given in respective columns in the tabulations.

All figures given in the table are the group average for ten watches. They reveal that at some magnetizing field strength between 36 and 360 lines per sq.in., the watches having bimetallic balances were sufficiently magnetized to be useless as timekeepers and remained so after removal from the magnetic field. In a field of 3600 lines they stopped and could not run again until demagnetized.

The ten watches equipped with elinvar hairsprings and mono-metallic balance wheels were not noticeably affected in a field strength of 36 or 360 lines. Even after exposure to a magnetic field of 3600 lines per sq.in., they were good timekeepers, resuming operation as soon as removed from the field.

A slight loss of time occurring after magnetization is not revealed in the foregoing tables, but the research showed that if an average elinvar watch were regulated to give perfect time before magnetization, it would lose approximately 6 sec. a day after being subjected to a magnetic field of 3600 lines per sq.in. This loss, however, is regular, as the variation in the daily rate caused by temperature and position runs parallel to the original rate, and is readily eliminated by moving the pointer on the regulator.

Watch repairmen report that rust is found on the hairsprings of six out of ten watches brought to them. The working range of stresses in a hairspring is much below its elastic limit, and therefore it is rare to find one rusted so badly that a corrosion pit can be blamed for breakage. (This, of course, is not true of mainsprings.) However, a tiny spot of rust on so small a member as a hairspring has a surprisingly large effect on the time-keeping qualities of a watch. Elinvar hairsprings have eliminated this cause of erratic timing, since they are not subject to corrosion in the atmospheric conditions under which watches are normally used.

We have, then, three important benefits arising from the use of elinvar: It eliminates the need for a cut-rim, bimetallic balance wheel, thus simplifying watch construction. It cannot be permanently magnetized. It is rustless, as far as watch use is concerned.

H. L. Beehler, Research Assistant of the Hamilton Watch Co., Testing the Elasticity of an Elinvar Hairspring

CORRESPONDENCE . .

. . AND FOREIGN LETTERS

Italian Electrodes Made of Natural Graphite

TURIN, Italy — Since there has been a large increase in electric steel manufacture in Italy during the last few years — essentially due to peculiar natural conditions in this country — the problem of producing good electrodes has acquired great importance.

Many years ago electrodes of "amorphous carbon" were abandoned by the majority of Italian electric steel works in favor of the less bulky electrodes made of artificial graphite, mostly imported from the United States. During the War, our steel makers were impressed with the danger of relying on one foreign source of supply for such an essential item of their industry. From that time they encouraged the production of good electrodes from Italian raw materials, or, at least, from materials supplied by different large markets at competitive prices.

Under the pressure of increasing competition, they were anxious to replace expensive American electrodes by some cheaper product, but graphite electrodes sold by various European works at much lower prices gave unsatisfactory results. Their use did not show any real economic advantage, on account of higher consumption and more frequent breakages.

Being aware of the great importance of this problem, I almost persuaded a large American corporation to erect a plant in Italy for manufacturing their excellent graphite electrodes, taking advantage of our low cost labor and power. Agreement seemed to be completed on all points, and the necessary capital had been immediately subscribed in Italy, but the American company eventually abandoned the scheme, probably because the directors had not sufficient confidence in the European situation immediately after the War.

Even then, the first experiments were started in Italy with two new types of electrodes, which quickly gave excellent results. They have been gradually adopted, and by 1924 monopolized a great part of the Italian market. They are, first, the continuous self-baking Söderberg electrode, and second, the natural graphite electrode.

Some information concerning the last-mentioned variety should be interesting, since they are manufactured now in large quantities from Italian raw materials by the Società Talco e Grafite Val Chisone in a plant near Turin.

This company owns huge deposits of talc and graphite and manufactures from it excellent electrodes of all the sizes required by the steel industry — that is, up to 22 in. diameter by 7 ft. long.

Two main problems had to be solved before high quality electrodes could be made with natural graphite, namely, to obtain a high electrical conductivity and, at the same time, a low combustibility.

High electrical conductivity has been achieved by a very ingenious patented process, based on a classification of the natural graphite according to its different structures, mostly lamellar and needle-shaped. Graphites belonging to the different structural classes are mixed to-

gether in given proportions and with the necessary binding materials to form a paste or pulp. This pulp is put through an extruding press under carefully controlled conditions, whereby the majority of the graphite particles are oriented in a single longitudinal direction in the electrode, forming something like a system of parallel wires. This eliminates nearly all the insulating effect exerted by the small quantities of binding materials remaining between the particles of graphite.

The problem of low combustibility — which is solved automatically in the artificially graphitized electrodes, where all the mass is transformed into slow burning graphite — is also of the utmost importance in masses of carbon which are baked at a comparatively low temperature, sufficient only to transform the tarry binding materials into coke. The Società Talco e Grafite has also solved this problem satisfactorily by a special treatment by which the coke, emanating from the binding materials, is completely enveloped by a layer of very fine graphite, protecting it from rapid oxidation.

FEDERICO GIOLITTI

Quick Determinations of Limiting Creep Stress

LONDON, England — Among the subjects which are engaging much attention at the present time among steel makers, engineers and investigators, is the behavior of metals at high temperatures. A full session of Section A of the International Congress held at Zurich in September last was devoted to this subject. There, as elsewhere, the problem which attracted the greatest amount of consideration was that of finding a reasonably quick method of determining the true power of resistance of a given material at high temperatures.

It has long been realized that an ordinary tensile test carried out at the usual rate of loading at temperatures much above 400° F. indicates a tensile strength of a far higher order than can be realized if the material is subjected to continuous loading at such a temperature for a long time. From the fact that under prolonged loading metals gradually extend or "creep" has been derived the idea as well as the name of the "limiting creep stress" (which is defined as the tensile stress which the material can bear, at the temperature in question, for an indefinite period without undergoing more than a definite and very small amount of extension).

The direct determination of the limiting creep stress is a very lengthy business, since exposures to the specified load and temperature of more than 10 days are frequently required. Also it is a matter of great difficulty, because the minute changes of length of the test piece have to be measured with extreme accuracy; "rates of creep" as low as 0.000 000 01 in. per in. per hr. have to be considered. Further, accurate control of temperature is also essential to a far higher degree than for most experimental work, since the "creep stress" varies rapidly with change of temperature. Accuracy of control of the order of half a degree (Fahrenheit) is now aimed at.

While tests of this kind can be and are carried out in well-equipped laboratories it is difficult to see how they can be used for routine acceptance purposes and it is natural that a demand should arise for a quick and easy method of testing. Unfortunately, there does not seem any immediate prospect of meeting such a demand satisfactorily and perhaps the best that can be done is to aim, as some investigators are doing, at a general correlation between the mechanical properties of the material which can be rapidly determined either at room or at elevated temperatures and its "creep" behaviour. There is still a good deal of disagreement as to the degree of correlation which can be expected, but if this can be placed on a satisfactory basis it should be possible to use a quick test for the identification of individual batches of material with a type whose true characteristics have been ascertained in a research laboratory.

Meanwhile two attempts at providing a quick means of ascertaining the value of the limiting creep stress have been made, one in Ger-

many by Rohn and one in this country by McCance and his collaborators.

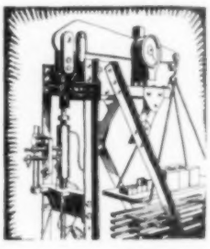
In Rohn's apparatus, the gradual stretching of the heated test piece under load produces a movement relative to an invar frame which will close an electric contact. This in turn alters the heat supply to the electric resistance heater which determines the temperature of the test piece. It follows that if the temperature and load are such as to produce appreciable stretching, the heating current will be continually diminished until stretching ceases to occur within the time during which the experiment is continued. If an autographic record of the temperature of the furnace is taken it will be found that the graph falls steeply at first and then more gradually until it finally appears to become horizontal.

It is suggested that when this graph is truly horizontal, the load acting upon the test piece represents the limiting creep stress for the temperature which the furnace has attained. The difficulty is that although an apparent state of stability may have been reached, it is not easy to be sure, with a sufficient degree of accuracy, when the temperature graph *has* become truly horizontal. There is also the risk that even if it has been horizontal for a long time, stretching may again set in.

In McCance's apparatus, the stretching of the specimens is very accurately measured under a given load and temperature and a time graph is again obtained which becomes horizontal for the limiting creep stress. This method is less automatic than that of Rohn, but is perhaps capable of greater accuracy (although ultimately it is subject to the same limitation mentioned above).

It is perhaps this limitation which gives rise to the most serious difficulty connected with the subject. It was shown as long ago as 1913 by J. C. W. Humfrey and the present writer that steel, when slowly strained at high temperatures, breaks by intercrystalline separation instead of the transcrystalline rupture which is usual at ordinary temperatures. Subsequently, D. Ewen and the writer showed that intercrystalline rupture occurs in all metals when slowly stretched at relatively high temperatures.

Modern investigation on the behaviour of engineering materials at high temperatures has shown that these conclusions apply in every case, provided that either the temperature is high enough or the rate of elongation sufficiently slow. The rate of elongation which accompanies intercrystalline movement (and ultimately rupture) is, however, exceedingly slow and the total amount of stretching which can occur in this way is very limited. The result is that if the conditions are such as to favor this type of rupture, the test piece may remain under load for a very long time, undergoing only the most minute amount of stretching and may then rupture with comparative rapidity and very little further stretching.



This kind of behaviour is sometimes interpreted as "intercrystalline cracking," as if it resulted from an embrittlement of the material. Nothing is further from the facts, since the material, if rapidly tested just before rupture, would show practically its original ductility. It is, in fact, a special type of rupture, akin to fatigue fracture, in that it occurs with little plastic deformation even in a ductile material. The engineer's demand for "ductility" at high temperatures is therefore liable to be misleading if interpreted in terms of possible extension under "creep" conditions, while, on the other hand, more rapid methods of estimating "creep" resistance may be vitiated by the intervention of intercrystalline rupture.

The whole subject is full of interest and importance both to engineers and metallurgists. It is being extensively investigated at the National Physical Laboratory and in the research departments of a number of British steel works and engineering firms, so that rapid progress in our knowledge of these important properties of materials is likely to be made.

WALTER ROSENHAIN

International Testing Congress Discusses Impact and Cast Iron

PARIS, France — The New International Association for Testing Materials, reconstituted in 1927 in Amsterdam, held its first congress at Zurich last September. More than 15 nations were represented at the initial meeting, when Dr. H. F. Moore spoke in the name of the United States and the writer in the name of France.

The meeting had been thoroughly prepared and organized; all the communications presented had been summarized in three languages. The reports relative to metals, the only ones in which we are now interested, treated of the five following subjects: Cast iron, resilience, fatigue, mechanical tests of metals at high temperatures, progress of metallography.

All but one of communications on cast iron discussed mechanical tests. The exception was a contribution from Pearce on his studies on superheated metal.

While the authors discussing cast iron, Messrs. Dubi, Pisek, and Piwowarski, seemed at first to be rather divergent in opinion, they appeared afterwards to agree on many points, particularly on the use of the bending test and the present impossibility of finding general relations connecting the results given by the different methods of testing, or of allowing an inference about the strength of castings to be drawn from the strength of test pieces, separately cast. The resistance of the casting is the only useful data for the user and his engineer, whereas the foundryman alone is interested in the resistance of test pieces separately cast.

A series of five communications gave the present status of the notched bar impact test in Germany, England, and Italy.

In Italy, Mesnager's test piece is used. This is a square piece, 10x10 mm. in cross-section, with a round-bottomed notch 2 mm. wide reducing the central area to 10x8 mm. In Germany the form of piece was studied by a joint committee of producers and consumers, which recommended Mesnager's test piece but with a notch 3 mm. deep. In France all the steel works and the well-informed consumers (at the instigation of the Society for Aeronautics, which adopted it in its 1917 convention) also employ Mesnager's test piece.

It would therefore seem possible and most desirable to come to an understanding on this point. It would be of considerable advantage in permitting one to compare the results obtained in different countries. For this purpose, an unofficial committee was constituted under the chairmanship of Dr. Rosenhain.

Several branches of endurance testing also were under review. Messrs. Ludwick, MacAdam, Gough, Schulz and Buchholtz advanced ideas regarding the relation of the endurance limit to figures derived in other static or dynamic tests — such as the well known tension, bending or torsion test — of a notched or an un-notched test piece and with or without mild corrosive surroundings. In this session it was particularly evident that there is a need of a more precise vocabulary — undoubtedly many questions arose in the minds of those present which were caused by a misunderstanding of the speaker's terminology.

The five communications on the progress of metallography form a remarkable review of the various branches of this science. J. L. Haughton's report dealt with metallographic technique and apparatus; F. F. Lucas discussed microscopy at a very great magnification; W. Guertler summarized the evolution of our knowledge on the analysis of alloys; A. Westgren emphasized the advantages of X-ray analysis; and Benedicks and Loefquist added an interesting chapter to their very valuable and complete work on the inclusions in steel.

Especially remarkable were the photomicrographs shown during the reading of the reports and during the discussion. Worthy of particular mention are Lucas' high magnifications of martensite, showing cracks 250 atomic diameters wide and 1000 atomic diameters long, and the colored ones obtained in polarized light by Professor Schwartz.

When the printed reports of the various meetings are studied, they will be found to be so voluminous and the opinions so diverse that it will be difficult for the reader, without having previously studied the subjects in detail, to appraise the present state of the problems studied or to determine the controversial points on which all the writers agree. To make such an important series of discussions accessible and useful to all those who are interested in the testing of materials, it is to be wished that the transactions at the various sections should be prefaced by a summary, pointing out the questions at issue and the conclusions which may be drawn.

From that point, committees should be appointed to coordinate and continue the work. Thus true international cooperation will be effected. It must be mentioned that a first step was taken along these lines at Zurich by a gathering of metallographists, which made a further effort toward the creation of an international bureau of metallography, a project the writer has already mentioned in METAL PROGRESS for December, 1930.

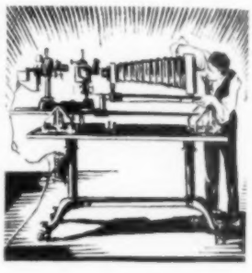
A. PORTEVIN

Distribution of Oxide and Sulphide Inclusions in Steel

DÜSSELDORF, Germany — Many investigations have been made on the segregation of elements throughout a steel ingot, but the distribution of metallic inclusions has been studied very little. The results of a thorough research into this subject, published at length in *Archiv für Eisenhüttenwesen* for December, 1931, will be of interest to American steel men, particularly since the notable studies in Pittsburgh by Dr. Herty and his associates into the subject of clean steel have brought the matter prominently to mind.

J. H. S. Dickenson was the first to prove that the distribution of non-metallic inclusions does not correspond to the segregation in the ingot. (See *Journal* of the British Iron and Steel Institute, 1926.) He studied samples from different positions in the ingot and extracted the inclusions, finding that they are larger and more numerous in the bottom of the ingot than in the top. But this method determined only the silicates, not the sulphides.

To get a true picture about the distribution of inclusions, it was necessary to count the number on numerous 25-ton electric furnace heats which were poured into ingots of about 3 tons weight. The results sometimes agreed with those of Dickenson, but there were also some ingots which showed exactly contrary results. It seemed, therefore, necessary to study the distribution of the different kinds of inclusions, that is to say, the distribution of the sulphides and of the oxides and silicates (which represent the two main groups).



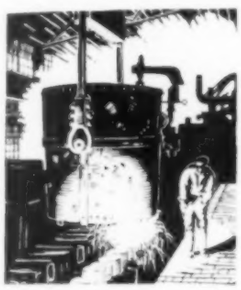
This done, everything was clear at once. The silicates and oxides were more numerous in the bottom of the ingot, a result in conformity with Dickenson's studies, and the sulphides were more numerous in the top, in conformity with the segregation. All those ingots which showed more inclusions in the top at the first count (without discrimination between sulphides and oxides) contained essentially sulphide particles and relatively few oxides or silicates.

It is easy to understand that the sulphides are more numerous in the top of the ingot, since sulphur also segregates in the top of the ingot. However, it is not so clear why silicates should be more numerous in the bottom of the ingot, because it is well known that silicon is an element which does not segregate markedly. It must then be a property of the oxides in general, and can be explained as follows:

If a liquid steel bath contains solid slag particles, it is very likely that these solid particles are the starting points for crystal formation. Any particle which is solid at such a high tem-

perature will probably have a very high content of silicon oxide, as can be seen by glancing at a few slag equilibrium diagrams. If the slag within the steel bath is still in the form of liquid droplets, it is less probable that these drops will be the nuclei for the formation of iron crystals.

But that is also possible, according to Benedicks' book on "Non-Metallic Inclusions in Iron and Steel," if the liquid particles are silicates or oxides, because they may lower the carbon content of the steel immediately surrounding by reacting with carbon and forming carbon monoxide. The iron around these liquid slag particles, which is now lower in carbon content, will freeze earlier than the remaining liquid with a higher carbon content. That means that a liquid oxide may also indirectly form the starting point for crystallization. The crystal around such a slag particle grows and finally becomes so heavy that it sinks. In this way a cone-shaped mass is formed on the bottom of the ingot, which contains (at least in its lower part) some very pure iron, together with by far the larger part of the silicate or complex oxide inclusions.



For sulphides the conditions are very different. Liquid sulphide particles cannot act as starting points for crystallization, because carbon in the surrounding liquid steel bath does not react with sulphur. Furthermore, solid sulphides, which might form nuclei, are much more rare at bath temperatures (say 2700° F.) than solid silicates, because their melting point is much lower — that of iron sulphide, for instance, is 2180° F. They will stay in the liquid portion until the end and freeze with the last part in the segregation zone at the ingot top. Hence the reason for sulphide particles concentrating themselves where carbon is highest.

Knowing the reason for the different distribution of inclusions, it is much easier to prevent their formation. We see clearly that the melting point and the composition of the inclusions are of the greatest influence on their formation and retention in the finished metal.

Oxide and silicate inclusions are the more dangerous. Not all these are alike, however, for common iron silicates have a melting point of about 2800° F., whereas the manganese silicates melt at about 2200. That means that an addition of manganese to the steel bath at the right time will favor the elimination of silicates.

For the formation and the elimination of oxide inclusions two main points have to be considered. First is the ratio of manganese to silicon during the melting and working period; and second is the condition of the melt when the alloying elements are added. If the manganese is high at the beginning of the melting period, large droplets of silicates with rather high manganese content and rather low melting point will be formed. Such inclusions can be liquated easily, because they are large and are formed early. Low manganese in the charge will favor the formation of small silicates with a high melting point, which are especially dangerous if they appear during the later stages of the heat. If we add an alloying or scavenging substance which contains larger amounts of silicon and carbon than the incompletely deoxidized steel bath, the silicon will be oxidized to SiO_2 and a part of the carbon to carbon oxide (which further favors the formation of SiO_2 during later additions of ferrosilicon). Only if the steel bath is completely deoxidized before we add the alloying elements, is there no liability that silicates may be formed.

In accordance with the foregoing principles, deoxidation with silicon and manganese is always to be preferred to deoxidation with silicon alone, because in the first case an iron-manganese silicate with a lower melting point will be formed. Further, it is advisable to add the manganese before the silicon, so there will be enough manganese metal dissolved in the steel bath to form a low melting iron-manganese silicate after the addition of the ferrosilicon.

WERNER ZIELER, Ph.D.

New Studies on the Nature of Abrasion

OSAKA, Japan — Despite a considerable number of published researches, the relation between abrasion and the nature of the material has remained obscure. Some experiments were therefore suggested by Dr. Honda and executed by the writer at the research laboratory of Sumitomo Steel Works.

The apparatus used was an Amsler universal wear-testing machine, turned through 90° to put the axis of both test pieces in a horizontal position. This insures uniformity of effect of the metallic powder or grit produced at the contact surfaces — a matter of great significance in abrasion experiments.

In this machine, when both the right-hand and the left-hand disks (turning at 220 and 200 r.p.m. respectively) were made of the same material, the piece rotating at the lower speed wore faster than the one at higher speed in ratio of 1.7 to 1. (Abrasion was measured by loss of weight.) When the hardness of the pieces tested against each other was different it was found that if the test piece of higher hardness rotates at a higher speed, the amount of wear in each piece is smaller than in the reverse combination. Finally, when the powder produced was continually wiped off the abrasion fell to about 1% of that which occurred when the powder was not removed.

The present writer proposes the following explanation of the mechanism of abrasion on the basis of the results briefly summarized in the above.

The surface of any material, even if it may appear to the naked eye to be very smooth, has innumerable microscopic protuberances like the teeth of a gear wheel. If such surfaces come into repeated contact during rolling or sliding under a certain pressure, the protuberances on these surfaces of contact break down by fatigue, giving rise to new *(Continued on page 90)*

Role of Sulphur in Corrosion-Resistant Steels

READING, Pa. — Issuance of a patent for a high-sulphur free-machining stainless steel, some four years after the application was made and after commercialization of the idea, recalls to mind certain conditions which were then retarding the industrial development of this useful metal.

Stainless steel was first manufactured commercially in this country as early as 1917, and by 1928 there were dozens of different analyses, thousands of different applications, and the tonnage manufactured annually had assumed considerable importance. Throughout this entire period, however, development had been seriously retarded by the fact that it could not be machined with standard tools at anything like production speeds.

Machining trouble was only one of a series, resulting from the fundamental nature of high chromium-iron alloys, and which may be termed "high frictional quality." It causes the chips to adhere to the cutting edges, forming what is commonly known as a "bug." This bug causes the tool to tear rather than cut the metal, and so much heat is generated that both the speed of machining and the finish on the job are seriously lowered.

Turning could be done by grinding the top rake on the tool to a very steep angle, whereupon the chips would skid off and would not form a bug, but twist drills, taps, solid dies, and intricate tools could not be altered so easily.

Cold drawing operations on wire and tubes had to be done after metallic coatings of copper or lead were applied, so the high chromium steel would not contact and load up the drawing die, thus scratching the surface of the work.

Similarly, grinding and polishing were very expensive and laborious due to the fact that the particles abraded from the chromium steels would quickly load up the grits on the abrasive and so overheat the *(Continued on page 88)*

A

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CONCENTRATES

from current . .

literature . . .

RECENT improvements to rolling mills at South Chicago plant of Illinois Steel Co. are described in *Mechanical Engineering* for January. First is a 51-in. blooming mill in which 18-ton ingots are prepared for rolling into wide flanged or H-beams. The reversing bloomer has two driving motors set at different levels, direct connected to top and bottom rolls, thus eliminating the usual stand of gears. Motors are variable speed, draw direct current from a motor-generator set, and are kept at precisely matched speed by automatic control. Shafts have roller bearings and forced-feed lubrication. The new **ROLLING MILL** for wide flanged beams has three stands of rolls, placed close together. The first stand is driven and works on the web. Next are non-driven rolls with vertical axes for rolling the top and bottom flanges. Last are non-driven edging rolls (horizontal axes). Screw-downs on each stand are motor operated, and the motions interconnected on a master program controller so that all three stands are correctly and quickly set for each successive pass by closing a single switch. The shear for this mill has two motors, a small one for acceleration and a large one for the actual cutting. Transfer of power at correct speed is effected by a huge Bendix drive.

IN the correspondence columns of *Mechanical Engineering* for January, Ernst Seidewitz discusses the design of die casting machines. Discarding the down-flow type as obsolete, he favors the up-flow over its more common competitor wherein the liquid metal enters the dies in a more or less horizontal path. He claims the following points of superiority for up-flow **DIE CASTING MACHINES:** (*a*) The assembly of moving die and its ejector pins can be more readily transferred to or from a bench and lined up in operating position, since all its attachments to the main frame are readily accessible. (*b*) Motion of the gooseneck, up and down, is simpler and under better control than the rather complicated path in most level-flow machines. (*c*) Splashing is minimized because much of the spray will fall back into the pot.

AN interview with a "leading American rolling mill man," printed in January's *Metal Industry*, cites the installation of powerful machinery of modern design whereby the **BRASS AND COPPER MILL** may achieve an output of standardized products equal in tonnage to that of a pre-War merchant steel mill. The expert was quoted as anticipating a consolidation of activities whereby a single blooming mill will supply slabs to a series of finishing mills for both brass and copper. Four-high rolling mills were first developed to a large extent for copper strips, and adopted by the steel industry with enthusiasm, but some unfortunate mistakes were made in later installations where steel mill equipment was installed in brass mills. "Full-mills" of the Steckel type have been used in two plants for radiator brass. Both styles should cut costs deeply in the finishing stages. Tandem rolling of strips and sheets has been delayed by an unsuccessful experience with brass some years ago, "wherein the matter was held secret and the full benefit of steel experience was not received." The first continuous mill for copper rod was started a couple of years ago, and two looping mills of advanced design were installed last year. *(Continued on page 74)*

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CONCENTRATES

COST and nuisance of annealing cold rolled material at frequent intervals in the process are avoided in large measure by a new process of rolling developed by A. P. Steckel of Youngstown, Ohio. Details of construction of some large mills recently installed are given in *The Iron Age*, Jan. 14. Mr. Steckel found experimentally in a 4-high mill that work hardening of STEEL STRIP, and the necessary annealing, decreased as the rolls were decreased in diameter. There is a limit, however, because very small rolls will not grip the strip and force it through, except when set for very small reduction. The alternative was to idle all four rolls in the stand, and *pull* the strip through. Action is then much like wire drawing, wherein the rolls act as an adjustable die. Power reels are therefore set at both sides of the rolls, and the strip is drawn back and forth by alternately shifting the proper gears or

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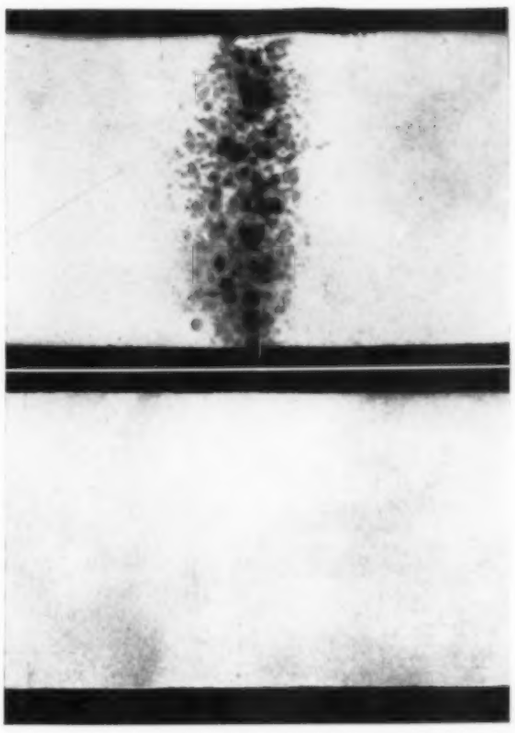
clutches. A necessary amount of back tension is given by a built-in hydraulic brake acting on the unloading reel. Water-cooled guide rolls are set on both sides. Since the work is under heavy tension at all times, it is finished with superior flatness and constancy of gage. Production achievements cited are: 36-in. steel strip from 0.065 to 0.003 in.; 18-in. stainless steel strip from 0.0125 to 0.007 in.; 6-in. copper strip from 0.187 to 0.004 in.; all without intermediate anneal.

IMPROVEMENTS in cast iron were prominently mentioned in "Automobile Engineering Progress" by Austin M. Wolf in *S.A.E. Journal* for January. Nickel and chromium additions to cylinder-block irons are now practically universal; an interesting variant being molybdenum-chromium electric furnace iron used in Hercules engines. Tin-plated **CAST IRON** pistons, adopted the year before by General Motors for rapid "run-in," are also being installed by Studebaker. Cadillac cast iron pistons contain molybdenum. "Owing to the improved structure made possible by centrifugal casting, the use of cylinder liners no doubt will increase." The same has caused much activity in brake drums. "Centrifuse" is a ribbed steel ring forming the mold; in it is cast an iron liner, and this unit is welded to the back of a disk wheel. Another interesting braking ring is made of a mill section of S.A.E. 5140 steel, hooped, butt welded, sized, normalized to give good structure and then welded to back of wheel plate. Information on the good wearing properties of high grade iron brakes has caused similar material to be adopted for some clutch plates.

STATUS of chromium plating was discussed by William Blum before a recent meeting of the Franklin Institute (its *Journal* for January). In this he paid most attention to the decorative or "bright" **CHROMIUM PLATES**, rather than the thick, "hard" plates for wear resistance described by Zimmerman in METAL PROGRESS last June, although he expressed the



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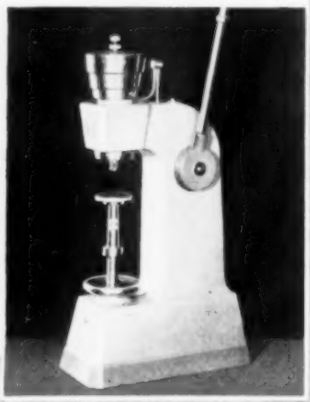

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CONCENTRATES

opinion that the future advances would be in such fields as the paper, textile, and chemical industries, whose equipment must resist combined corrosion and abrasion. He also foresees an interesting future for electroplates of other metals, such as tungsten and those of the platinum group. In the plumbing industry he cites with approval the use of chromium plated 18% nickel brass; the colors match well and such fixtures should have indefinite life. They should be covered with heavy grease during the construction period, and until all tile work has been cleaned — the hydrochloric acid used for the latter purpose has ruined large installations.

DEVELOPMENT of track-laying tractors of high speed for war purposes has been contingent upon the track links and "grousers," according to Col. C. G. Mettler, writing in *Product Engineering* for January, 1932. Pre-War designs suitable for slow-speed tractors become unserviceable by wear at pins and links. Lubrication of these points has proven too complicated, and mud and dust cannot be effectively excluded. Up to date, the best design permits 600 miles operation at 15 miles per hr. It is made of short duralumin **TRACTOR LINKS** with blunt sawtooth bottoms, connected together with hardened steel pins working in hardened steel bushings. Further advance is expected by the use of rubber bushings. This would be relatively thick, pressed into a corrugated hole in the link, and a corrugated pin driven through its center. All movement would then be confined to elastic flow within the body of the rubber itself.

BY altering the design of the five new 10,000-ton cruisers of the New Orleans class, and **WELDING** an unusual number of joints, the U.S. Navy will be able to put at least 1000 tons more armor on them than is carried by the vessels of the Pensacola class, according to Hanson W. Baldwin in *New York Times*, Jan. 3. This additional mass of armor and deck protection will *(Continued on page 78)*

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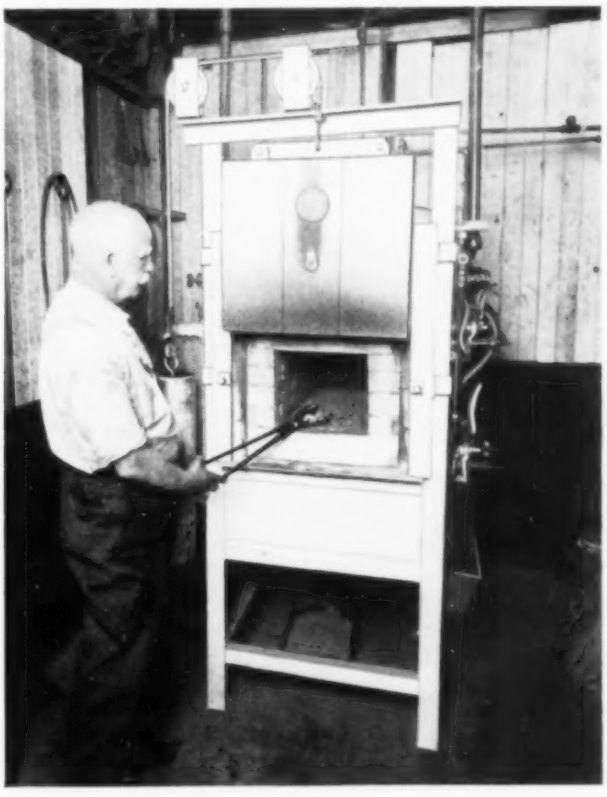

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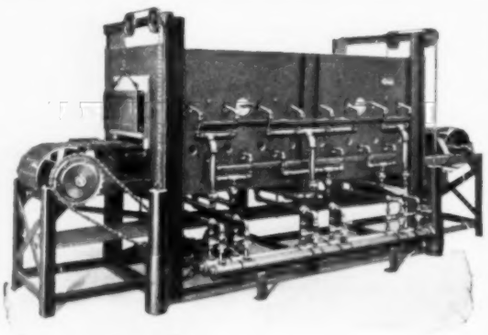

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CONCENTRATES

(Cont. from page 76) protect the ship's vitals from damage by direct hit of 8-in. shell fired from 15,000 yd. All main transverse structural members in the New Orleans are joined by welding, and not a single rivet exists in the forward 88 ft. of the hull.

NICKEL-CHROMIUM cast iron makes superior stamping dies and has been widely adopted by the automotive industry, according to Herbert Chase in *American Machinist* for Jan. 7. For **DIES** to be finished by hand, Brinell 200 may be secured by annealing a machinable casting at 1500° F. Castings containing 3% Ni, 0.75% Cr, 1.5% Si, 248 to 270 Brinell, can be readily machined if the cast section is not chilled. Brinell 300 can be obtained in the untreated castings with nickel 5.5%, chromium 0.5%, and even higher hardnesses and wear resistance are secured from lower alloy analyses by quenching in oil from 1550° F. and drawing to 400° F. Most of the analyses recommended by Mr. Chase can be produced from a semi-steel cupola mix in automotive foundries without a special charge for a small quantity of dies.

SHEETS for deep drawing can best be produced by cooperation between steel mill and press shop, in the opinion of R. O. Griffis (*S.A.E. Journal* for January), because failure may result either from improper steel or from such things as improper die lubrication or insufficient trimming allowance. "Grain structure is by far the most important feature of the modern **DEEP DRAWING** sheet." Micrographs indicate "ideal structure for an extra deep drawing sheet" with equi-axed ferrite grain of about 0.0007 in. mean diameter (as closely as can be measured on the half-tone). Drawing qualities improve as grain size becomes even finer, although the sheet may become too stiff. Such fine grain results from relatively rapid cooling after normalizing, and can only be achieved in continuous strip or sheet — packs of two or more on carrier sheets cool too slowly.

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REVIEWS OF RECENT PATENTS

By Nelson Littell
Patent Attorney
Member of A. S. S. T.
22 East 40th St.
New York City

Alloy Steels, *by Walter R. Breeler, Detroit. 1,831,946; Nov. 17.*

Alloy steels covered by this patent are free machining and may be cast or forged. They may also be nitrided without distortion. The alloy may be made in the standard type of furnace of either the open hearth or electric arc or other type, and to a suitable charge of open hearth or Bessemer steel is added a charge of molten metal to bring the analysis up to the desired final alloy. The final mixture may be made either in the furnace or in a ladle, and after a thorough mixing the alloy is cast into suitable ingots for further shaping. An alloy with the following composition is found to be eminently satisfactory for a large number of uses: Carbon, 0.25%; aluminum, 1%; manganese, 1.2%; sulphur, 0.2%; phosphorus, 0.05%; silicon, 0.2%; chromium, 1.5%; molybdenum, 1.5%; and the balance iron. Such steels are cheap, tough, and may be readily shaped and machined.

Annealing Box, *by Percy E. Hunter, Pittsburgh. 1,832,933; Nov. 24.*

This effective sheet steel annealing box has adequate strength and rigidity, and will not collapse when highly heated. Its end walls are provided with flanges to which the side plates and a top plate are welded. The upper edge of each side plate is turned in to form a flange, and corrugations are provided to reinforce the end plates against bulging, similar corrugations being provided in the top plate. Tie members extend across the base of the corrugations in the base and are welded to both sides. In this manner the corrugations are prevented from spreading under the influence of high temperatures. The top is welded to the side plates.

(Continued on Page 82)

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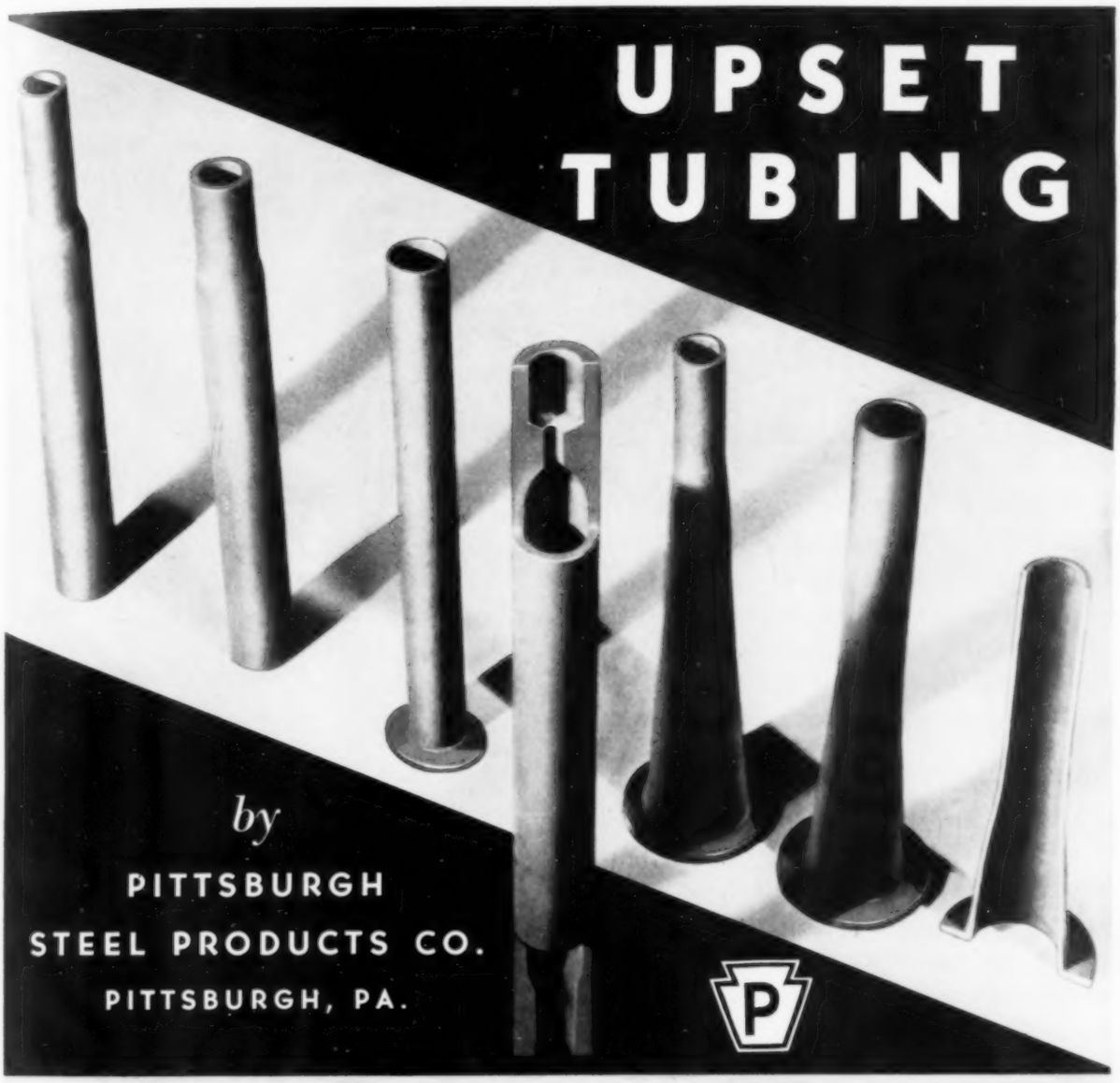

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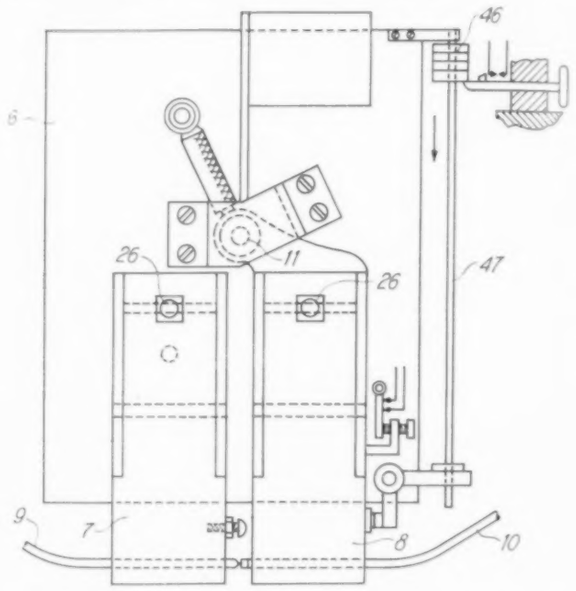
Welding Apparatus, *by Claude Siebs, Cranwood, N. J., and Thomas A. Daniel, Maywood, Ill., assignors to Western Electric Co. 1,833,660; Nov. 24.*

To overcome the usual difficulty of weakened physical structure at the weld formed by welding copper wires or rods, sometimes known as burnt copper, this apparatus was devised. As



shown, the two jaws 7 and 8 are supported by a back plate 6, and the wires 9 and 10 to be welded are supported in the jaws and held in abutting relation. The jaw 8 is mounted on a pivot pin 11 while the other jaw is preferably fixed. A cam arrangement operates the lever 26 which thus forces the jaws together. A releasable weight 46 is mounted on a slide rod 47 and when it drops it will force the parts firmly together and also will simultaneously close the switch in the control circuit.

Metal Cleaning, *by Harry S. George, Massapequa, N. Y., assignor to Electro Metallurgical Co. 1,832,979; Nov. 24.*

Metals can be cleaned so as to produce brightened surfaces having the characteristic color of the metal by this method which will remove oxide films without attacking the metal. Pyrophosphoric acid is used and the metals are treated at a temperature preferably between 160 and 250°C. A strip of rustless iron cleaned with this acid becomes perfectly smooth and unetched.

(Continued on Page 84)

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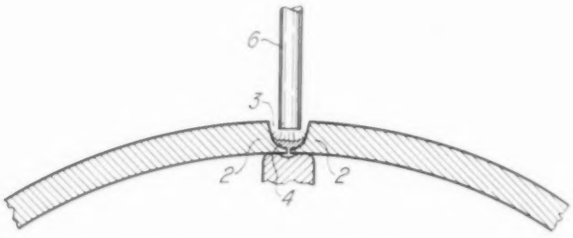
Chicago Cleveland Indianapolis Detroit Montreal, Canada

Electrically Welded Pipe, *by Howard J. Burnish, Milwaukee, Wis., assignor to A. O. Smith Corp. 1,830,783; Nov. 10.*

Under this method of arc welding longitudinal seams of tubular articles such as pipe, the pipe blank is formed from a flat sheet of metal. The side edges 2 of the sheet are chamfered to form a welding groove 3 for receiving the weld metal 4 which is deposited by the electric arc from a fusible metallic weld rod 6 which may be fed



automatically at a rate as desired. To provide proper penetration of the weld at the ends of the pipe, however, it is necessary to hold the edges apart a predetermined distance at each end, while maintaining them closer and preferably in contact throughout the intermediate portion of the seam. The increased distance between the edges at the ends of the seam facilitates the penetration of the weld throughout the full length of the seam.

Electric Resistance Alloy, *by William E. Ruder, Schenectady, N. Y., assignor to General Electric Co. 1,833,723; Nov. 24.*

This alloy is suitable for withstanding high temperatures in air without excessive oxidation and is useful as electric resistance heating alloys. It has an iron base and contains from 15% to 35% chromium, and from 5% to 12% aluminum. To improve physical qualities about 1% of a suitable grain refining purifying element such as titanium, zirconium, vanadium or the like, may be added. This element, however, usually goes off into the slag. The alloy may be forged or drawn and has improved durability under high temperatures and sufficient resistivity to generate the required amount of heat. It may also be cast and made into annealing boxes, furnace structures, etc. It is preferably made in an electric furnace having a basic lining to preserve the silicon in the lining. The iron and chromium are melted in the furnace and then tapped on to preheated aluminum.

Cold Finished Bar Bulletin—Joseph T. Ryerson & Sons, Inc. Bulletin describing the wide variety of shafting screw stock, and open-hearth case carburizing steels in use today. A range of products is given, a list of standard tolerances and S. A. E. specifications. Bulletin O-50.

Electric Steam Generators—General Electric Co. Booklet describing and illustrating G. E. electric steam generators for process work. A list of applications is included showing how these generators may be used in a wide variety of industries. Bulletin D-60.

Recuperators—Carborundum Co. The complete story of Carborundum Co. recuperators for industrial furnaces, describing the type and covering operating conditions. Bulletin F-57.

Optical Instruments—Bausch & Lomb Optical Co. has published a very attractive 128 page book which describes in detail the construction and use of optical instruments for examining and analyzing metals. Bulletin F-35.

Welded Construction Folder—Bethlehem Steel Co. Folder describing the use of rolled steel shapes and plates for the building of machinery parts by welding. The results are said to be sturdier construction, reduced weight, low cost, and elimination of patterns. Bulletin N-76.

Refractories—E. J. Lavino & Co. Literature on Kromepatch and Plastic K-N chrome ore refractories for industrial furnaces. Bulletin O-40.

Industrial Gas Heat—American Gas Association. A veritable textbook on the uses of gas heat in industry, profusely illustrated with photographs of installations, etc. Bulletin D-10.

Machine Heat Treating—American Gas Furnace Co. A 16-page illustrated booklet giving information on the various types of conveyor heating machines available for heat treating on a production basis. Bulletin D-11.

Potentiometer Pyrometer—The Brown Instrument Co. 16-page booklet explaining and illustrating the principal features of the new Brown potentiometer pyrometer with special reference to accuracy of operation and ruggedness in service. Bulletin N-3.

"Carbonol Process for Carburizing Steels" is the title of the new 12-page bulletin published by the Hevi-Duty Electric Co. The bulletin describes the results and advantages of the Carbonol process of carburizing. Bulletin N-44.

Fatigue Testing Machine—Thompson Grinder Co. Interesting data on fatigue testing and description of the rotating beam type of fatigue testing machine are given in Bulletin D-23.

Heat and Corrosion Resistant Alloys—Michigan Steel Casting Co. A 16-page bulletin describing and illustrating various cast, rolled and fabricated alloy structures for use at high temperatures. Bulletin N-12.

Globar Elements and Accessories—Globar Corp. A new leaflet containing a list of standard industrial type Globar electric heating elements and a coordinated list of terminal mountings and accessories. Bulletin N-25.

Furnace Parts—Driver-Harris Co. has issued a bulletin featuring furnace parts made of their alloys. This bulletin gives data and advantages of Nichrome and Chromax heat resisting alloys in the form of furnace parts. Bulletin N-19.

Automatic Metallographic Polishing Machines—E. Leitz, Inc. Catalog illustrating and describing the Guthrie-Leitz automatic polishing machines of the one, two and four-spindle types. The new Leitz specimen clamps are also described. Bulletin N-47.

Scale Prevention—Dearborn Chemical Co. Booklet describing latest scientific methods of treating water for prevention of scale, corrosion and foaming in steam boilers, dealing with related problems in connection with scale and corrosion in other power plant equipment. Bulletin D-36.

Industrial Application of the X-Ray—General Electric X-Ray Corp. Booklet gives many examples of the use of the X-Ray in the industrial field. Profusely illustrated with radiographs of castings, welds, assemblies, etc. Bulletin D-6.

Furnaces for the Steel Industry—The Electric Furnace Co. have issued a four-page folder illustrating and listing several electric and fuel fired furnaces of various types they have installed in steel plants. Bulletin D-30.

Modern Industrial Furnaces—Surface Combustion Corp. Booklet covering the research, development and engineering activities of the Surface Combustion Corp., and their application and the advantages obtained by S-C furnace users as a result of these factors. Bulletin N-51.

Metal Progress, 7016 Euclid Ave., Cleveland.

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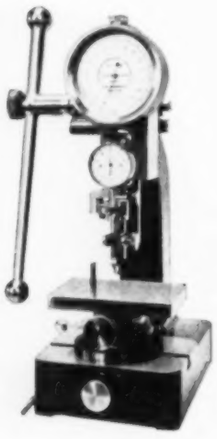

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DETROIT	MILWAUKEE	ST. LOUIS	WORCESTER

CORRESPONDENCE

(Continued from page 70) work that the wheel had to be continually dressed.

In 1928, the Carpenter Steel Co., with which the writer is connected, proposed the use of sulphur-bearing corrosion-resistant steels to correct this situation. A typical analyis is carbon 0.10%, chromium 14%, and sulphur 0.30%. Widespread use since that time proves that such material can be machined in automatic screw machines with standard shop tooling at speeds equal to, or closely approximating, those used for bessemer screw stock. The problems of drilling, tapping, and die threading were solved, and it was also found that wire and tubing could be cold drawn with no coating other than the lime coat and lubricants normally employed.

Such non-galling, non-seizing properties of high-sulphur "stainless" have led to its adoption for mountings in gate valves to prevent scratching when opened and closed, and in pump rods to prevent galling and scratching in the packings.

Chromium-nickel steels, also, of the 18-8 type not only possess high frictional properties by reason of the chromium, but, independent of this, they are extremely difficult to machine, and then only by ingenious tooling, because of their austenitic structure and their great toughness.

Addition of a little sulphur to these analyses has been equally beneficial to the cutting properties. Much data could be quoted — an illustrative instance is: A power hacksaw cuts the low sulphur 18-8 in 80 sec. as against 30 sec. for the free-machining type.

The corrosion resistance of these high-sulphur grades is just about the same as the low-sulphur types, and it is now common practice to use the free-machining grades and corresponding non-free-machining grades interchangeably. Generally, the buyer will use the non-free-machining types for parts which are brought to shape by bending, forming, or drawing, and use the free-machining type for parts which are machined to shape.

F. R. PALMER

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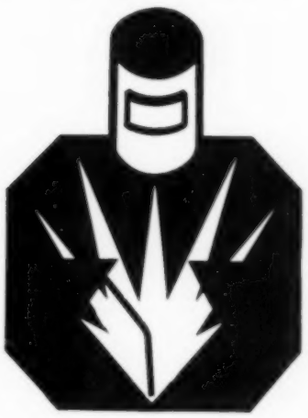
MUREX
BRINGS A NEW CONTROL TO WELDING



Are uncertainties a source of trouble in your welding? If they are, then you will welcome the new control which Murex Heavy Mineral Coated Electrodes bring to the welding operation. ¶ Murex Electrodes largely shift the responsibility for obtaining good results from the experienced operator, who has always shouldered it, to the electrode, where the responsibility belongs if welding is to be another dependable production operation. ¶ Murex control results from the action under the arc of the unique, heavy all-mineral coating on a Murex Electrode—an action, which through exacting care in manufacture, is always uniform in every Murex Electrode of the same type. ¶ Murex control gives the operator a "break". With a Murex Electrode, the operator easily holds a short, quiet arc by "riding" the electrode on the work. The heavy mineral coating both shields and spaces the arc, and there is an even, maximum deposit. Less metal is lost through vaporization and spattering. There are no objectionable fumes or smoke. And weld metal of unsurpassed strength and ductility is always deposited in a clean, round fillet or a smooth, flat bead, free from under-cutting. ¶ Murex Electrodes are made in 18-inch lengths in a number of types . . . for welding commercial mild steel, manganese steel, 18-8 stainless, and other metals. Write for complete details . . . promptly sent on request.

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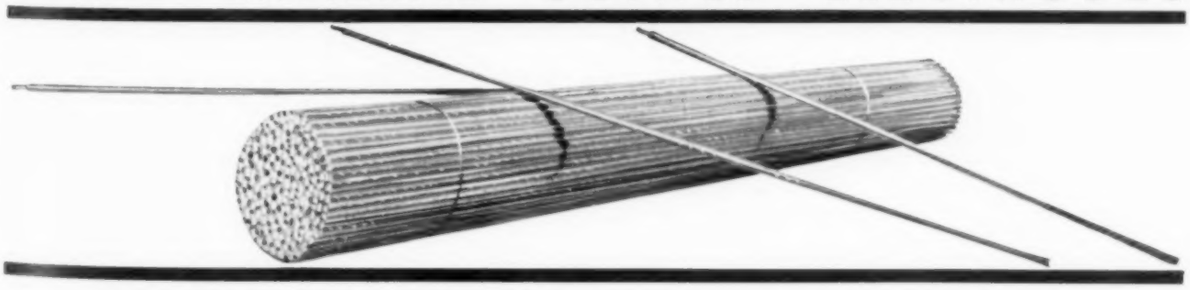
M U R E X
HEAVY MINERAL COATED ELECTRODES



Murex Electrodes are made in the United States by the American Murex Corp. and are sold only by the Metal & Thermit Corp., pioneers of welding and manufacturers of Thermit. Literature on Thermit welding for many kinds of heavy work sent on request.

(Continued from p. 70) protuberances. Abrasion is caused in this way, and the amount of the protuberances broken down is the amount of wear. The worn-off powder, present on the contact surface of two test pieces, plays the same role as the protuberances, or as saw-teeth, thus resulting in a greater amount of wear. If the powder is harder, it acts like the hard teeth of a saw and results in a greater abrasion than when it is not so hard.

When pieces of the same hardness are in true rolling contact the amount of abrasion on each will be equal. But when one rotates faster than the other, its area in contact in unit time will be larger, and a larger number of protuberances on it will come in contact with a smaller number on the slow-moving piece, causing a relatively greater destruction on the surface of the latter.

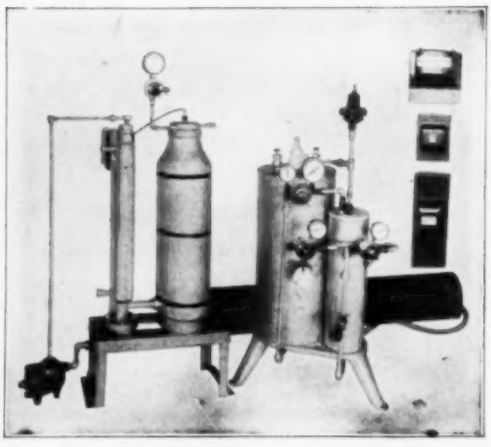
A similar line of reasoning gives a logical explanation of the result of the tests with disks of different hardness, when it is remembered that the most of the abrasion is due to a mixture of metallic dust originating in unequal amounts from the two wheels.

The above conclusion regarding abrasion may be applied to the design of bearings. If two contact surfaces consist of different materials, the harder one must be used on the side which has the larger contact area per unit of time.

The experiment also explains why wear at the side of a rail head is more damaging than wear on the top, because there is always slippage between hard wheel-flange and side of rail, whereas contact between wheel-tread and top of rail is almost a perfect rolling contact.

SEIZO SAITO

PREECO SPECIAL ATMOSPHERE EQUIPMENT



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